REPORT OF SURVEY CONDUCTED AT

NORTHROP GRUMMAN
DEFENSIVE SYSTEMS DIVISION
ROLLING MEADOWS, IL
MAY2000

Best Manufacturing Practices

1998 Award Winner

INNOVATIONS IN AMERICAN GOVERNMENT

BESTMANUFACTURINGPRACTICESCENTEROFEXCELLENCE
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Foreword

This report was produced by the Office of Naval Research's Best Manufacturing Practices (BMP) Program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP Program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at Northrop Grumman, Defensive Systems Division (DSD), Rolling Meadows, Illinois conducted during the week of May 1, 2000. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared*. BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

Northrop Grumman DSD is a vertically integrated facility which houses all major disciplines under one roof. The company covers the full spectrum of electronic warfare systems, from precision strike to self-protection to readiness and support. Among the best examples were Northrop Grumman DSD's accomplishments in miniaturized high power amplifier design and manufacturing; production process simulation; contingency planning; excellent performance indicators; integrated management control system; modular factory for electronic warfare component manufacturing; and rolling forecast system.

The Best Manufacturing Practices Program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on Northrop Grumman DSD expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Anne Marie T. SuPrise, Ph.D.
Acting Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

In the early 1930s, William J. Halligan founded the Hallicrafters Company in Chicago, Illinois. The company built handcrafted amateur radio receivers with state-of-the-art features at an affordable price. By 1938, Hallicrafters was the most popular manufacturer of communications receivers in the U.S. and 89 other countries. During World War II, many of Hallicrafters' products were pressed into service due to a shortage of military radio equipment. The company geared up for wartime production, and was responsible for many new designs and innovations (e.g., HT-4). After the war, Hallicrafters started a new line of consumer electronics including radio phonographs, AM/FM receivers, clock radios, and televisions. The 1950s were the most successful years for the company. Many of its amateur radio products became classics including the HT-32 and the SX-101. Much of this equipment is still used today and sought after by nostalgia buffs and collectors.

In 1966, Northrop Corporation bought Hallicrafters and moved it to Rolling Meadows, Illinois. Here, the new subsidiary's main function was to produce para-military equipment and electronic countermeasures systems for Northrop. In 1974, the site was designated as Northrop's Defensive Systems Division and renamed Northrop Grumman after the 1994 merger with Grumman Aerospace Corporation. Today, Northrop Grumman is a leading designer, systems integrator, and manufacturer of military surveillance and combat aircraft; defense electronics and systems; airspace management systems; information systems; marine systems; precision weapons; space systems; and commercial and military aerostructures.

With its corporate headquarters in Los Angeles, California, Northrop Grumman is organized into three business sectors, employs 45,000 employees, and achieved $9 billion in sales for 1999. The BMP survey focused on the Defensive Systems Division (DSD) of the Electronic Sensors and Systems Sector. Located in Rolling Meadows, Illinois, Northrop Grumman DSD employs 2,200 personnel, encompasses 50 acres, and achieved $536 million in sales for 1999. The company covers the full spectrum of electronic warfare systems, from precision strike to self-protection to readiness and support. In addition, Northrop Grumman DSD is a vertically integrated facility which houses all major disciplines under one roof. This approach promotes multi-disciplinary teamwork and allows for intelligent tradeoffs in all phases of program development. A key aspect of the company's success, and a best practice, is the Integrated Management Control System (IMCS). This system is a hybrid collection of integrated, high-end, commercially-available software which Northrop Grumman DSD tailored to its unique management and customer requirements. With its closed-loop Material Requirements Planning features, IMCS implements just-in-time policies that automate tools to establish and monitor planning, program performance, material management, supplier management, shop floor, capacity planning, and financial activities. IMCS also provides capabilities to communicate electronically to customers and suppliers. Other best practices documented were Northrop Grumman DSD's miniaturized high power amplifier design and manufacturing; production process simulation; contingency planning; excellent performance indicators; modular factory for electronic warfare component manufacturing; and rolling forecast system.

Through its dedication, ingenuity, and forward-looking vision, Northrop Grumman DSD maintains its focus on the changing needs of its military, government, and commercial customers. The company also fosters numerous initiatives to promote customer satisfaction, employee opportunity, environmental compliance, and community outreach. Just as the company strives to achieve technological innovation in business, it also endeavors to make valued contributions to the local community. This outlook encourages employees to look beyond traditional ideas and methods. Employees even formed a SCUBA club to remove debris dumped in local ponds and lakes. By employing fundamental principles, Northrop Grumman DSD ensures a bright future and strengthens the company's position to compete. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at Northrop Grumman DSD:

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Application Specific Integrated Circuit Design Capabilities	9

Application Specific Integrated Circuit design capabilities have become relatively common in response to the

Item	Page
Hazardous Materials Management Program	**19**

Northrop Grumman DSD established the Hazardous Materials Management Program to provide users with a more cohesive set of tools and information for managing hazardous materials. The program utilizes the Hazardous Materials Manager, a searchable database and display software package, which provides an integrated and systematic approach to managing activities (e.g., acquisition, day-to-day handling, final disposal, regulatory reporting requirements). The database is continuously updated and offers on-line accessibility for employees through network computers.

Pollution Prevention Program **20**

Northrop Grumman DSD's Pollution Prevention program evolved from a waste minimization subcommittee initiated by the Environmental, Health, and Safety Management in 1987. Today, the company has taken its program a step further by developing the Annual Environmental Operating Plan. This plan integrates the procedures, projects, and goals which make up the company's pollution prevention strategy.

Site Recycling Efforts **20**

In 1992, Northrop Grumman DSD set up a Recycling program which focuses on several recycling initiatives including periodicals, newspapers, wooden pallets, toner cartridges, glass and plastic bottles, fluorescent bulbs, and scrap metals. The company strives to minimize employee effort by enlisting support from its janitorial service contractor.

Excellent Performance Indicators Program **20**

In 1992, the company initially set up the Excellent Performance Indicators Program to encourage problem-solving skills and employee empowerment. This initiative has since evolved into an employee empowerment and recognition program based on metrics that measure team performance. The program rewards team accomplishments, provides the necessary tools to monitor data-driven performance, and encourages process improvements directed at reducing costs.

Commodity Design Teams **21**

In June 1999, Northrop Grumman DSD developed the Commodity Design Team process. This process strives to create a win-win situation by driving down costs while maintaining an equivalent or higher profitability throughout the value chain. As a result, the Commodity Design Team was able to focus Northrop Grumman DSD and its key suppliers toward a common vision and set of objectives by leveraging their combined knowledge, technology, facilities, and purchasing power.

Item	Page
Integrated Management Control System	**22**

In 1974, Northrop Grumman DSD implemented an enterprise-wide, paperless system for Manufacturing Resource Planning, known internally as the Integrated Management Control System. This system is designed to synchronize production and delivery throughout the value chain. Transactions are processed on-line and in real time to ensure that program objectives are being met.

ISO-9001 Quality Management System Audit **23**

In 1999, Northrop Grumman DSD consolidated its ISO-9001, process, and software audit systems into the ISO-9001 Quality Management System Audit. This system uses a singular electronic data system for auditing and consolidates the audit planning activities. The company also created an annual report, the ISO-9001 Annual Quality Management System Health Status, which covers audit topics. Together, these tools provide Northrop Grumman DSD with greater visibility and access to audit results.

Modular Factory for Electronic Warfare Component Manufacturing **24**

Initiated in 1996, the Modular Factory for Electronic Warfare Component Manufacturing program is a joint Department of Defense-Northrop Grumman DSD vision to address the needs of the evolving electronic warfare market. The program's goals are to achieve market-driven products, faster product development, reduced product cost, simplified product design, and market leverage through functionality and manufacturability.

Process Oriented Contract Administration Services **25**

In June 1992, Northrop Grumman DSD and the Defense Contracts Management Agency set up a government initiative known as the Process Oriented Contract Administration Services. The initiative operates as a formal contractor/customer mechanism to address problems, resolve issues, and facilitate improvement initiatives. This relationship is mutually beneficial and unique in industry.

Product Assurance Reporting and Trending System **26**

In 1995, Northrop Grumman DSD implemented the Product Assurance Reporting and Trending System to enhance its operations by consolidating its stand-alone corrective action systems into a single integrated database. This database standardizes data for nonconforming material reports and corrective actions; provides consistent, reliable historical data; is easily modified for

Information

The following information items were documented at Northrop Grumman DSD:

Item	Page

Point of Contact:

For further information on items in this report, please contact:

Mr. Thomas Fallon, Jr.
Northrop Grumman Corporation
Electronic Sensors and Systems Sector
Defensive Systems Division
600 Hicks Road
Rolling Meadows, Illinois 60008
Phone: (847) 259-9600 x5628
Fax: (847) 506-7972
E-mail: falloth@mail.northgrum.com
Web: http://www.northgrum.com

Section 2

Best Practices

Design

Application Specific Integrated Circuit Design Capabilities

Application Specific Integrated Circuit (ASIC) design capabilities have become relatively common in response to the demand for small, high-performance electronics in Department of Defense (DOD) systems. However, the Northrop Grumman, Defensive Systems Division (DSD) has effectively prioritized its efforts to focus on client requirements. The company's well-integrated ASIC design capabilities (e.g., analog, digital, mixed signals) also provide many benefits for its existing products including improvements to performance, cost, reliability, repeatability, weight, and volume.

Northrop Grumman DSD refined its capabilities by incorporating a variety of elements into its process. These elements include experienced personnel, computer aided design (CAD) tools, a design database, and strategic foundry relationships. The company also uses system performance to take full advantage of available component performance, while providing repeatability and reducing labor requirements for the tailoring of radio frequency (RF) and digital functions. By reducing ASIC costs, Northrop Grumman DSD decreased production costs by a 3:1 factor and increased reliability by a 10:1 factor. Reliability improvements primarily involve the reduction of component levels and associated interconnections.

Since implementing its ASIC design capabilities, Northrop Grumman DSD has produced consistently good yield rates with timely deliveries. In addition, detailed knowledge and the monitoring of customer priorities enable the company to select the most appropriate design techniques and methodologies. Combined with good foundry vendor relationships, Northrop Grumman DSD can effect trade-offs that best suit its client requirement profiles. The company also uses available analysis and simulation tools to ensure success, and revises techniques for best results as industry processes evolve.

Circuit Card Assembly: Design Team

During 1995, Northrop Grumman DSD determined that its circuit card assembly (CCA) design and fabrication process incurred unwanted costs and scheduling impacts. To streamline and develop a more efficient process, the company set up an integrated process team for CCA design.

This cross-functional team, with representatives from every discipline connected with CCA design and fabrication, invoked a structured process. A key achievement is the team's commitment to work as a group to pull the design through the entire process, rather than passing the design from one stage to the next. Through its iterative efforts, the design team developed an efficient and structured process for the company's CCA design cycle. Sequential applications of this process have successfully achieved progressive improvements. Discrete portions of the process include design (e.g., electrical, mechanical); physical implementation (e.g., printed wiring board [PWB] layout); and fabrication.

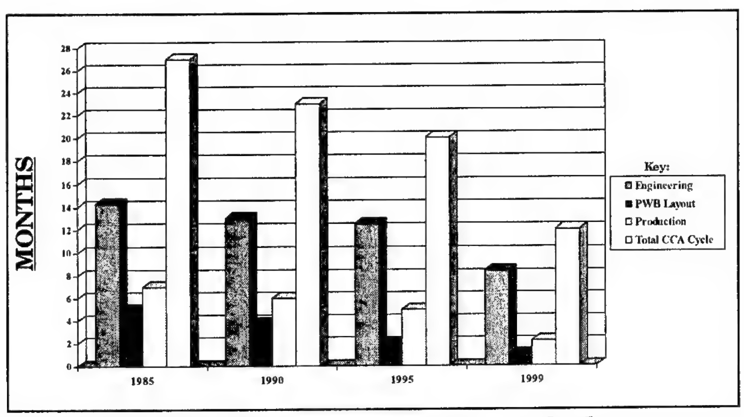


Figure 2-1. Circuit Card Assembly: Design Cycle

Key features of the CCA design and fabrication process include:

- A designated cross-functional team for each CCA that owns the design.
- A process roadmap that fully defines the sequence of activities in the CCA design process.
- Incremental design reviews that serve as gateways before proceeding to the next step.

- A sequential, two-step process for the PWB layout with part placement finalized before interconnections are routed.
- Process metrics which are established, monitored, and continuously refined.

Since being implemented in 1995, Northrop Grumman DSD's schedule for design was reduced by approximately four months; for PWB layout by more than one month; and for fabrication by over two months. Figure 2-1 illustrates the CCA: Design Cycle reductions of 52% through 1999. By reducing the scope of effort within certain activities, the company can tailor its process programs without downgrading the importance or quality of their outputs. Whenever tailoring is considered, Northrop Grumman DSD actively assesses the risks. In addition, active ownership of the design empowers and encourages team members to innovate and achieve improvements in the process.

Electro-Optical/Infrared Technology Development

In the past, Northrop Grumman DSD's practices in Electro-Optical/Infrared (EO/IR) Technology Development followed traditional military procurement procedures. These procedures involved many stages of prototype work; the development of platform/application-specific hardware; a reactive approach to customer needs; and minimal involvement with external vendors. Today, Northrop Grumman DSD's revised practices in EO/IR Technology Development emphasize the anticipation of customer needs as well as cost and schedule controls.

New product features and customer needs are anticipated and proactively developed by using Internal Research and Development (IRAD) funding. Modular system development allows a single system design to encompass many deployment platforms and streamlines upgrades. Strong vendor teaming at all stages of development assists in streamlining the design, and avoids schedule and resource impacts from miscommunication or unpreparedness.

Since implementing the revised practices, Northrop Grumman DSD has streamlined its prototype development by carefully assessing risk, and by designing and building prototypes to the highest possible level of completion during each design iteration. In addition, the bypassing of multiple breadboard and brassboard stages generates significant cost and schedule savings. The company's prototypes are capable of undergoing field testing with minimal special test equipment, and are more representative of the final product. Several programs at Northrop Grumman DSD have successfully implemented this design practice, including Wanda™, a pointing/tracking system; Viper™, a solid state laser; and Litening II, a forward looking infrared pod.

Infrared Countermeasures Simulation and Test

Heat seeking missiles are designed to track bright infrared aircraft sources such as engines and exhaust plumes. As the target maneuvers, the missile uses the changes in the timings of the detector modulation to track the target and determine course corrections. Infrared countermeasures (IRCM) systems, or jammers, broadcast an infrared beam which is modulated with timing characteristics that are similar to those used by the missile. If successful, the jammer flashes will either cause the missile to severely alter its flight course (causing a miss) or seek a false target position (optical breaklock). In the past, Northrop Grumman DSD performed IRCM simulations in an open-loop configuration with limited aircraft vulnerability and technique assessment capability. In addition, no measure of miss distance was possible with an open-loop test, which leads to over-design of the jammer source. Today, the company employs unique, multi-level simulation facilities to support IRCM development. These facilities ensure successful simulations and live-fire tests under customer scrutiny.

Northrop Grumman DSD's approach has minimized the development cost and design-to-production schedule, while maximizing the cost-performance trade-off. The company uses a variety of hardware-in-the-loop simulation resources and digital simulation modeling tools for developing RF and IR countermeasures; refining waveform parameters; and evaluating effectiveness against threat systems. Many of these resources were built and are maintained by Northrop Grumman DSD specifically for these purposes. In addition, government furnished equipment and software legacy models are used to support the company's initiatives and contracted program efforts.

The company developed and maintains four levels of IR missile simulation of increasing complexity and fidelity. These simulations involve the following test configurations: an open-loop rate table facility; an atmospheric optical path; an all digital-based, closed-loop simulation suite; and a full degree-of-freedom hardware closed-loop facility. Each is used at a different stage in the evolution of the IRCM design.

The open-loop simulation is used in the requirements definition phase, and the effects of the atmospheric transmission are determined with the aid of the rooftop testing facility. During the design phase, the all digital simulation capability is used to determine the subsystems sensitivity. The design optimization is accomplished with the aid of the close-loop simulation and then subjected to live-fire verification. These tools are continually upgraded and adapted by Northrop Grumman DSD as the latest threat information is obtained through traditional channels as well as unique testing opportunities.

Miniaturized High Power Amplifier Design and Manufacturing

In the past, Northrop Grumman DSD created transmitter/amplifier assemblies by interconnecting separately packaged components into a large line replaceable unit or shop replaceable unit. These assemblies were quite large in size and volume, which often limited or prevented their use in tight volume applications. In addition, the assemblies typically encountered high voltage interconnect problems. To resolve this situation, the company pioneered a new process for designing and manufacturing miniaturized high power amplifiers that use microwave power modules (MPMs).

Northrop Grumman DSD's MPM approach integrates a solid-state front end with a small, high-efficiency traveling wave tube and a miniature integrated power conditioner into a common package. By using a smaller single case, the company reduced the number of high and low voltage interconnects. Additionally, the modular construction of MPMs decreases integration time and simplifies troubleshooting. The high degree of commonality between different MPM types results in the economies of scale for reduced cost and inventory, and a well-characterized material history.

The miniaturized high power amplifier design and manufacturing approach fosters innovative system architectures which were not feasible with the previous method. Since implementing the MPM approach, Northrop Grumman DSD achieved a 21% reduction in design cycle time; a 48% reduction in total hybrid labor; and a 62% reduction in manufacturing cycle time. All future electronic warfare systems will employ towed and/or remote located transmitters. The MPM approach will enable the company to provide very high degrees of miniaturization and performance.

Modeling and Simulation for Requirements Definition

Previously, Northrop Grumman DSD used past experience and limited analysis to formulate the system requirements for electronic warfare systems. Typically, the system requirements were either underestimated leading to poor system performance, or overestimated leading to excessive system cost. Today, the company combines digital modeling and simulation with engineering analysis to develop and ensure accurate system requirements.

Building on its 18-plus years of experience in modeling and simulations, Northrop Grumman DSD developed a library of modeling and simulation tools to support its system requirements definition tasks. These tools have enabled the company to reduce the cost of test and evaluation activities. The specifics of electronic warfare systems require knowledge in the fundamental areas where the simulation tools will be applied: the phenomenology, engagement, and mission levels. Although system requirements are derived from all sources, they generally are processed through these levels of simulation.

Using primarily government sponsored and supported models, Northrop Grumman DSD is developing models and methodologies to address specific issues and pursue multiple approaches to confirm, validate, and cross-check the results. Figure 2-2 shows a high-level block diagram for countermeasure technique development. Modeling in the phenomenology domain is geared toward physical assessments and environmental impacts on system performance such as effects due to clutter, weather, terrain, aerodynamics, or obscuration. System effectiveness requirements are derived through direct interaction with each applicable weapon system through all phases of an engagement, including search, acquisition, target tracking, missile guidance, and intercept. Operational system requirements are established by modeling a representative operational mission scenario and observing multiple threat handling characteristics and platform survivability.

Each flight test costs approximately $50,000 to $60,000. Since implementing the modeling and simulation for re

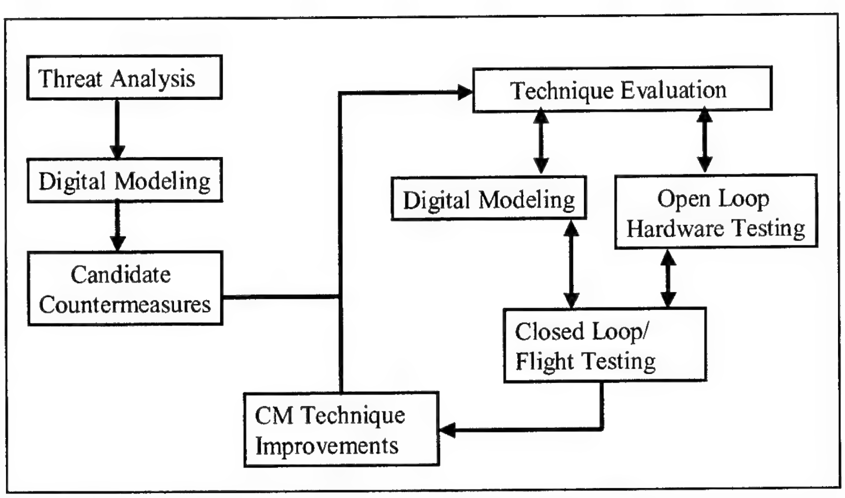


Figure 2-2. Countermeasures Technique Developmet

quirements definition, Northrop Grumman DSD has significantly improved the performance level of systems being designed and reduced the number of flight tests required.

Monolithic Microwave Integrated Circuit Design Tools

Previously at Northrop Grumman DSD, designing custom circuits and monolithic microwave integrated circuit (MMIC) prototypes were not cost-efficient practices. Time and associated cost were a significant part of the overall development cost, and prototyping required the maintenance of a large Research & Development stock. In the 1990s, the company developed MMIC design tools to improve these practices.

In 1992, Northrop Grumman DSD established the MMIC Cell Library which helped reduce the time and cost associated with designing custom circuits. Containing more than 300 of the most frequently used designs, the MMIC Cell Library facilitates MMIC cell reuse and minimizes circuit re-invention. In addition, the designer has access to all MMIC foundry processes' information required for reuse. The MMIC Cell Library enables the company to reduce its design time by one-third compared to the previous practice.

In 1996, Northrop Grumman DSD developed the Rapid Prototyping System which increased design and prototyping efficiency. The company implemented this prototyping method for fabricating MMIC-based subassemblies. A complete inventory of custom and off-the-shelf GaAs MMIC devices, components, and thin film networks is maintained in the MMIC Research & Development Prototype Laboratory. The Rapid Prototyping System enables the company to produce prototype MMIC hardware in a matter of hours for various internal and external customer requirements.

Additionally, Northrop Grumman DSD implemented a Peer Review Procedure for MMIC design that eliminates more than 90% of the design errors during tile creation. This procedure also eliminates about 15% of the design errors before tile design release, and complements the availability of the reference libraries. Designers have assigned mentors who guide them in the use of tools and practices. All libraries are electronically checked on a weekly basis for updates or changes. After a tile is created, a final layout design rule check is performed. Stream data is then converted back and again verified against the original data. Once the tile data is committed to fabrication, this data along with any modifications created at the foundry is stored in a reference library.

All MMIC design schematics, simulations, layouts, and subsequent measurements are documented in a MMIC library database. Since implementing its MMIC design tools, Northrop Grumman DSD has decreased design cost by 20%; design cycle time by 40%; manufacturing cost by 40%; manufacturing cycle time by 40%; and inventory by more than 30%.

Test

Instrumentation and Data Reduction Tools Development

Seeking a way to collect and analyze data in a timely and comprehensive manner, Northrop Grumman DSD took a consolidated approach which encompassed both the laboratory and field environments. The company established a method that addresses the data collection and processing of RF and IR instrumentation.

The basis for this practice incorporates a composite assessment of system requirements, system objectives, and customer verification and validation (V&V). Early identification of requirements (both system and data) aid in maturing the product and associated instrumentation and data reduction development. A clear statement of objectives, likewise, assists in prioritizing the development of instrumentation and data reduction features. Additionally, a similar focus on customer V&V needs enables the final product to perform equally well in the laboratory and field environments. The associated commonality or reduction of support equipment brings the expected cost avoidance while also establishing a robustness criteria, normally only associated with very mature laboratory instrumentation and data collection.

Data reduction is available in real time with prompt post-mission environments available to the customer. To adequately support product requirements, instrumentation is required to support a range of features that encompasses company development and integration as well as customer development and acceptance test needs. The complexity of RF and IR testing dictates very capable data processing and recording provisions. Both features contribute to real-time analysis and detailed post-mission analysis capabilities.

Incorporation of laboratory, development, and field test capabilities within a common hardware item provides scheduling ability to support the customer's program schedule right from the outset. Provisions have included operation onboard aircraft as well as unmanned units that telemeter encrypted data. Ruggedized enclosures have permitted operation in rigorous environmental locations and conditions.

Software routines provide significant flexibility in the selection and use of operational modes and screen presentations to suit pre-flight, in-flight, and post-flight conditions. The inclusion of capable data processing and recording provisions supports a variety of diagnostic and analyti-

cal features that demonstrate the readiness to enter flight testing. The selectable displays of real-time parameters permit early confidence in results as well as efficient retesting where required. Based on lessons learned, Northrop Grumman DSD has already identified improvements that can enhance its next generation of instrumentation.

Production

Best Value Manufacturing

Like most defense contractors, Northrop Grumman DSD manages multiple programs within a single facility. In the past, each program operated under its own quality plan based on individual contract requirements; specified its own array of redundant testing, reporting, and inspection requirements; and generated its own manufacturing processes for specific customer requirements. This approach produced redundant processes and failed to recognize the similarity among the programs. To resolve this situation, Northrop Grumman DSD established Best Value Manufacturing (BVM) as a quality assurance method for the fabrication, assembly, inspection, testing, and delivery of electronic systems, components, and spares which meet or exceed specified customer requirements. The method was developed through a culmination of lessons learned during the manufacture of over 4,000 electronic warfare systems as well as a teaming effort with suppliers and customers.

BVM specifies a single, common set of manufacturing and quality assurance (QA) processes based on commercial and industry standards, specifications, and test methods. In addition, BVM fosters the DOD's Single Process Initiative (SPI) and is applicable to current/future military and commercial products produced at Northrop Grumman DSD. BVM supports performance-based specifications, allowing the company to determine the minimum test, inspection, and data requirements for the product to meet end-item requirements. Next, BVM passes quality responsibility for the manufactured product to the (internal or external) operator or organization producing the product. This approach greatly reduces the need for independent oversight, excessive data requirements, and other non-value-added costs. BVM does not, however, change the specified performance or reliability required by the applicable system or end-item specifications (e.g., power levels, frequencies, vibration, temperature range, reliability levels) for the piece-parts, assemblies, or final installed system.

Also used for contract proposals, BVM enables Northrop Grumman DSD to specify common manufacturing and quality assurance packages for all new programs, but still provide flexibility for tailored requirements. The main difference from the previous method is that each tailored requirement requested by the customer incurs a specific cost break-out for changing the standard BVM package. As a result, the customer can see the actual cost associated with the special request, which helps them make informed decisions on whether the benefit is worth the extra cost.

Northrop Grumman DSD is currently using BVM on its production ALQ-135 and ALQ-162 programs, and has recently submitted an SPI proposal to incorporate BVM on all programs. Since implementing BVM, the company has reduced the cost of the ALQ-162 Block 4 as much as 50% from Lot 3 by eliminating unnecessary tests, inspections, and reports. Northrop Grumman DSD also decreased its QA organizational size by over 70% without adversely affecting product quality. Concurrently, the company reduced material lead times by 50% to 70%; incoming backlogs from 2,000 to 34 lots; and incoming inspectors from 70 to five. The QA, Program Office, and Contracts organizations are working together to ensure that all proposals generated for future business specify the BVM approach.

Calibration Delinquencies

Calibration delinquencies are the result of equipment being in use beyond the calibration due date, and are directly related to the scheduling method for the calibration process. Previously at Northrop Grumman DSD, each equipment custodian received a due list that indicated which test equipment needed to be calibrated within the next 30 days. This handwritten method provided insufficient notification and was prone to data entry errors. As a result, delinquent items were a common occurrence. Late notices were then sent to organizational supervisors followed by second notices to the department heads. This reactive approach also created a strained working relationship among all involved parties.

In late 1993, Northrop Grumman DSD revised its method for scheduling equipment calibrations by setting up a two-step process. On the first day of each month, the equipment custodians receive a 45-day projection of the laboratory's calibration needs. Additionally, a short list is posted daily and alerts the custodians to items due that day or the next, which have not been returned to the calibration laboratory. This calibration scheduling method enables three equipment custodians to handle over 6,000 items.

By using a proactive method, Northrop Grumman DSD decreased the number of delinquent items from more than 40 in 1993 to zero in 1996, and continues to maintain this level today. Additional benefits from this method include timely out-of-tolerance identification, reduced risk of using out-of-tolerance equipment, a 30% reduction in administrative tasks, and a good working relationship among all involved parties.

Calibration Intervals

Previously, test equipment at Northrop Grumman DSD was calibrated on an arbitrarily chosen interval of six months. If a piece of equipment was within its tolerance limits three consecutive times, then the calibration interval was increased by one month. If it was out of tolerance once, then the calibration interval was decreased by one month. This process resulted in confusion due to having many different intervals for the same equipment models. Additionally, the company experienced frequent manufacturing test station shutdowns for calibrations; numerous requests for priorities and due date extensions; a backlog of more than 1,000 items; and an increase in items being outsourced. In 1994, Northrop Grumman DSD developed a revised method to optimize test equipment calibration intervals and maintain a maximum in-tolerance rate.

Northrop Grumman DSD's method employs the U.S. Air Force's 33K-1-100 guidelines document as the basis for setting the initial calibration intervals. In addition, the company uses a five-year analysis for each family of test equipment to adjust the intervals. All equipment calibration needs are reviewed quarterly to determine if the equipment is still in excess of the 95% in-tolerance limit (per family of equipment).

Since implementing its revised method, Northrop Grumman DSD has realized a 60% reduction in backlog; a 50% improvement in turnaround times; and a reduction in calibration outsourcing which has increased quality. In addition, the average calibration interval has increased from nine months in 1994 to 16.9 months in 2000, and manufacturing test station shutdowns for calibrations now occur only twice a year.

Circuit Card Assembly: Cleaning

Prior to the Montreal Protocol, Northrop Grumman DSD used Freon TMS to clean contaminants (predominately flux) from CCAs. This procedure was performed after each soldering operation within prescribed time limits. With the initiation of ozone depleting chemical (ODC) regulatory mandates in the mid-1990s, the company began developing a non-ODC cleaning process to replace its traditional chlorofluorocarbon cleaning methods.

Northrop Grumman DSD replaced its previous CCA cleaning method with an automated semi-aqueous process that used a non-ODC compound (Axarel) and a closed-loop, zero-discharge system for the process liquids. This approach improved the cleaning process capability twenty-fold, eliminated more than half of the associated operations, and decreased ODC emissions by 39 tons per year (Figure 2-3). Additionally, the closed-looped system provided a significant reduction in process waste. The entire system only needs to be shutdown approximately every 12 to 18 months for cleaning and solvent replacement.

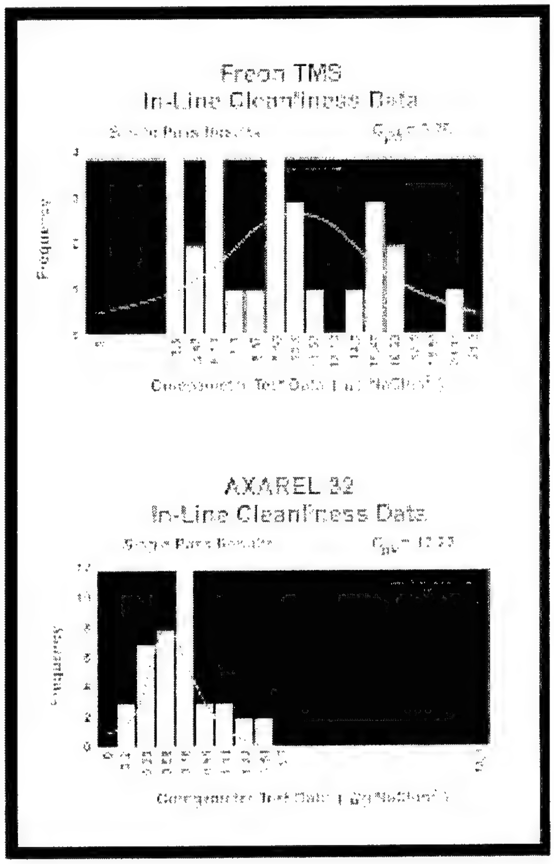


Figure 2-3. In-line Cleanliness Data

By changing to an automated, non-ODC-based cleaning system, Northrop Grumman DSD increased its cleaning performance, reduced the cleaning operation steps by 56%, and realized more than $2 million in conservation savings on ODCs. Lessons learned from using this process include:

- Equipment design and ventilation helped minimize the cleaning agent odors.
- Since closed-loop filter membranes did not last as long as expected, they were replaced with carbon/mix bed resins.
- Bacteria growth must be monitored in solution tanks, and can be controlled through periodic heating and chlorine-flushing during solution replacement.
- Although higher temperatures clean and rinse better, they must be weighed against increased air emissions.
- Application limitations exist with some assemblies due to non-submersible parts.

Circuit Card Assembly: Flexible Manufacturing

In 1985, Northrop Grumman DSD produced approximately 110 card assembly types for its programs. Prototype CCAs were typically assembled in Engineering with limited involvement by Operations personnel. Process capabilities were validated on new designs during a first build. Over the years, the development and manufacture of CCAs drastically increased in complexity and variation. To meet this challenge, the company developed a unique CCA flexible manufacturing line to meet the entire site's needs for CCA production. Today, Northrop Grumman DSD produces more than 530 different card assemblies.

The CCA flexible manufacturing line is designed for low-volume, high-mix environments. Operator training, equipment selection, and process development are targeted to achieve the versatility necessary to process prototype, pre-production, or experimental assemblies for Advanced Engineering as well as the substantially higher production quantities that may become commonplace in future programs. Additionally, the line's arrangement, as a series of highly flexible islands of automation, provides the company with the ability to design and implement new lean processes which are not constricted by existing equipment and/or process flows. Thus, the CCA production line is completely independent of programs, packaging technology, specification requirements, or other factors; and can accommodate new state-of-the-art equipment technologies with only minor disruptions.

To ensure that designs produced by Engineering remain compatible with the efficient production of the CCA line, Operations instituted a Design for Manufacturability process. Producibility engineers within Operations act as liaisons between Engineering designers and the CCA process' engineering function to develop and impose design guidelines; review design drawings for manufacturability; and act as a coordination point for prototype and pre-production builds. The latter responsibility enables the liaisons to be aware of process results, thereby staying current on production capabilities and the company's ability to build new technologies efficiently.

The CCA flexible manufacturing line significantly impacts Northrop Grumman DSD's production and developing programs. Other Northrop Grumman site designs may now be produced at the DSD facility as new programs are moved in. The technology transfer between Engineering and Operations ensures timely funding of new process development activities to meet production schedules. Design for Manufacturability activities have also provided part and design standardization benefits. In one case, the company was able to eliminate more than 20% of the unique components from a product design. Prototype builds can now be used to validate manufacturing process capabilities.

Components Obsolescence Management

In 1975, the defense industry had a 17% share of a $4.2 billion semiconductor market. Twenty years later, this percentage shrunk to 0.7% ($1.1 billion) of a now $150 billion semiconductor market with the commercial industry consuming the balance (Figure 2-4). Demand for specific integrated circuits (ICs) from the defense industry was overshadowed by the commercial industry's requirements, despite increasing device complexities of new military designs. Additionally, defense requirements called for 20-year replacement part availabilities even though the typical life cycle for logic family parts were three years and eight years for passive components. With IC parts being discontinued at a rate of 34,000 per year in 1998 (an average of 153 daily discontinuance notices), Northrop Grumman DSD set up Components Obsolescence Management to address diminishing manufacturing sources.

Northrop Grumman DSD previously used performance to determine design, and then used design to determine the parts needed. The company's new approach is to use performance and cost goals to determine design and the parts needed. The goals of Components Obsolescence Management are to:

- Decrease product and development costs by reducing the number of active parts.
- Decrease the number of suppliers.
- Shorten product time-to-market by reducing approval time.
- Improve product quality by controlling the number of preferred parts.
- Improve component information knowledge and speed of part selection during design, procurement, and manufacturing.

Components Obsolescence Management uses various tools that assist Northrop Grumman DSD's personnel in the selection of design components for programs. The Preferred Parts Selection List (PPSL) uses various factors (e.g., hardness, reliability, safety, platform) to maintain the company's current database of over 17,000 parts. Product Data Management tools (e.g., Aspect's Explore, TACTech, Metaphase II) help standardize parts as well as reduce or eliminate parts with short life cycles. Additionally, comprehensive information such as obsolescence, re-use, life cycle data, parametric data, cost, reliability, approved sources, and diminishing manufacturing sources can be tracked, sorted, and compiled by using these management tools.

Since 1996, Northrop Grumman DSD's Intranet website has provided design and procurement personnel with information on obsolete specifications; changes in part selections, derating, and applications; hot links to other websites

for updated information; and obsolescence issues. By using the Intranet website, design personnel can also access the PPSL to research and select parts for new designs. This system can be customized to display specific parts lists based on the program of interest, thus preventing extrinsic parts from being selected. Personnel can also use a standardization effectivity program to get a rough indicator rating on how well their design has utilized standard components, even providing comparisons with previous designs.

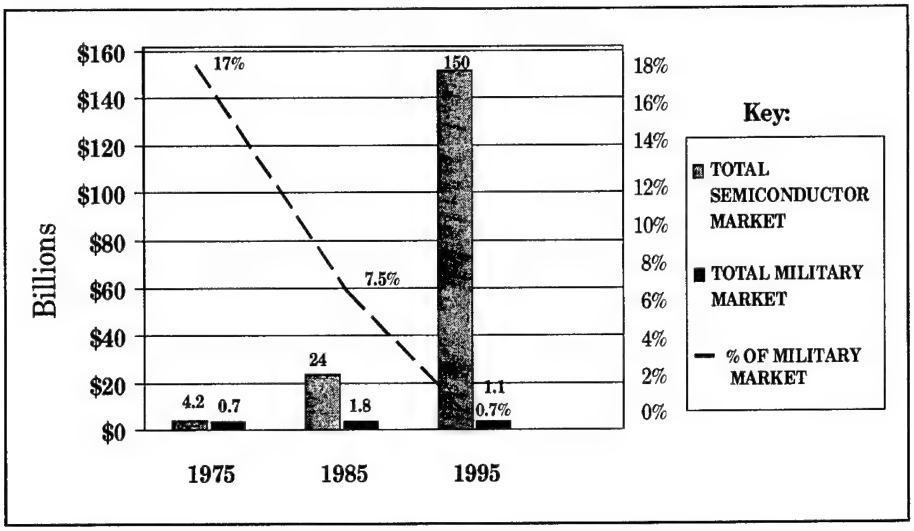


Figure 2-4. Declining Military Presence

Components Obsolescence Management has made an immediate impact at Northrop Grumman DSD. Of the 35 systems in production during the last five years, none have required an obsolescence-related redesign. Based on a typical three-redesigns-per-program requirement, the company achieved a cost avoidance of around $52 million. In addition, the on-line PPSL information has generated an estimated annual savings of 24,000 hours in engineering research. By using the collective industry knowledge of these management tools, Northrop Grumman DSD continues to provide fully supported, quality products which are cost efficient and competitive.

Operator Self-Inspection and Product Assessment Program

Prior to June 1997, Northrop Grumman DSD's in-line inspections required a quality control inspector to perform 100% product checks at identified operations throughout the build of a product. Although production operators and inspection personnel received identical workmanship training, only the operators were responsible for their particular application with no accountability for the product acceptance. To improve this process, Northrop Grumman DSD transferred the responsibility of product in-process acceptance from the inspection organization to the manufacturing organization by establishing the Operator Self-Inspection and Product Assessment program.

The Operator Self-Inspection and Product Assessment program utilizes the production operators' experience and training for product acceptance throughout the manufacturing process. This approach builds quality into the product rather than tries to inspect quality into the product. The program provides formal training and certification for the operators. Once they successfully complete the classes, operators are issued a unique stamp for acceptance of product and then must undergo 30 days of on-the-job training. Afterwards, operators can perform their own in-process inspection, acceptance, and sign-off. Inspections are limited to the tasks in which the certification is held.

The Operator Self-Inspection and Product Assessment program reinforces the personal responsibility of tasks. As a result, inspection personnel have become assessors of the process and product, while acting as coaches to the operators. Rather than 100% in-line inspections, random daily assessments of hardware and documentation are made to detect any errors made by operators during the manufacturing processes. Corrective action can then be done in real time while the work is still in the pipeline. The program also enables Northrop Grumman DSD to use defect summaries for its operators which provides a systematic method for identifying training needs.

Production Process Simulation

Previously, Northrop Grumman DSD used various low-level tools to make production capacity and product mix decisions. Spreadsheet models assumed level-loaded tasks by using constant manpower throughout the production cycle. Fixed cycle times did not take into account resource availabilities. Equipment tended to be suboptimized which reduced the overall operation's efficiency. Any gaps in information were filled in through managemen judgementand experience. As a result, these tools failed to realistically

depict the true dynamics and interrelationships of the manufacturing processes. In 1992, the company resolved this situation by implementing simulation modeling software.

Simulation modeling allows system developers and analysts to predict the performance of existing or proposed systems under different configurations or operating policies. This process, carried out before the existing system is actually changed or the new system is built, minimizes the risk of unforeseen bottlenecks, under- or over-utilization of resources, and failure to meet specified system requirements. Northrop Grumman DSD uses its simulation capability to support equipment purchases; view the production impact of a changing product mix; analyze and reduce cycle times; review scheduling practices; select optimal lot sizes; analyze staffing needs; review factory layout changes; and assess just-in-time methodologies. By using statistical distributions to define manufacturing variabilities, the company increases the validity of the simulations.

Advanced uses of the Production Process Simulation include data downloads involving inspection and test yields, non-labor related wait times, and weekly batch loading data from the Material Requirements Planning (MRP) system. Northrop Grumman DSD also created two large models: (1) a Shop Operations model with over 1,000 assembly variations, and (2) an MIC/Hybrid model containing more than 850 assemblies. By employing these models and Design of Experiment techniques, the company can perform sensitivity analyses to determine the impact of up to ten input factor changes.

Since implementing Production Process Simulation, Northrop Grumman DSD has completed more than 50 simulation modeling projects. Among the capabilities of this predictive tool are equipment justification, fine tuning of existing programs, future project requirements in resources and training, and layout improvements. In one case, the company used the modeling simulation to analyze its conversion plan for the non-ODC cleaning of CCAs. The simulation showed that current and future production levels could be supported with just two Detrex batch cleaners. Prior to the simulation, Northrop Grumman DSD had planned on purchasing three or more batch cleaners. As a result, the company realized an avoidance cost of $100,000 in capital expenditures.

Facilities

DSD Contingency Planning

Prior to 1997, Northrop Grumman DSD lacked an integrated emergency management system plan. Although several independent plans existed, they were maintained by different groups within the organization. Security controlled some areas while Environmental Health and Safety Management handled others. Since the application of these various plans lacked consistency, employee awareness of emergency management activities was low. To resolve this situation and comply with corporate and regulatory requirements, Northrop Grumman DSD developed and implemented the DSD Contingency Plan.

This single, integrated plan contains information regarding Northrop Grumman DSD's one million square-foot facility on a room-by-room basis, and provides a floor plan showing the locations of rooms, offices, laboratories, and shops. The DSD Contingency Plan also lists the number of occupants in each area; all potential hazards and safety concerns; and the names and phone numbers of personnel to be contacted in the event of an incident. An Area Emergency Coordinator is appointed for each area and is responsible for auditing and maintaining the information at that location. In addition, the plan is maintained from a single source site, and employees can access emergency management information by using the company's Intranet website. Updates are posted daily to ensure the most current data is available.

The DSD Contingency Plan has enabled Northrop Grumman DSD to easily maintain and distribute the latest emergency management information throughout the facility. Employee awareness of emergency procedures have significantly increased, resulting in safer working environments. As a safeguard, the company stores duplicate electronic and paper copies of the DSD Contingency Plan at off-site locations.

Energy Management

Previously, Northrop Grumman DSD lacked a formal energy management program. The company experienced recurring high energy costs of $4 million per year; funding limitations; and inadequate or insufficient Heating, Ventilation, and Air Conditioning (HVAC) energy control capabilities. In 1994, Northrop Grumman DSD formed an Energy Management Committee to identify and implement strategies for reducing energy consumption without hindering ongoing business operations or compromising employee safety.

One of the Committee's accomplishments was the use of Direct Digital Controls (DDCs) on air handlers, chillers, and boilers. DDCs enabled Northrop Grumman DSD to optimize equipment performance, extend the life of HVAC units, and provide centralized computer-based diagnosis of HVAC out-of-tolerance conditions for prompt action. In addition, the company participates in peak shaving on critical summer days. Peak shaving is a conservation energy program between Northrop Grumman DSD and its

local power provider. On high-load days, the company is asked by the local power provider to reduce its energy draw off the grid by 500 kilowatts. To achieve this request, the company engages its local backup generators and reduces non-critical power usage (e.g., hallway lighting) at the facility. In return, the local power provider pays Northrop Grumman DSD a favorable rate for the power reduction off the grid.

Additional accomplishments include:

- Installing occupancy sensors in conference rooms.
- Using DDCs to turn off lights and HVAC equipment throughout the facility during non-business hours.
- Purchasing and storing natural gas through a broker, allowing the company to realize an annual savings of $40,000 to $60,000 since 1995.
- Retrofitting lighting with electronic ballasts and T-8 fluorescent lights, allowing the company to replace 40-watt, four-bulb fixtures with 32-watt, three-bulb fixtures without compromising light intensity.

The Energy Management Committee also wanted to provide initiatives that employees could use in their own household environment. As a result, the company provides articles and information (e.g., energy programs, energy saving hints) in its newsletters as well as on its Intranet website. During Energy Day, a spokesperson from an energy provider interacts with employees to answer their questions and promote education and awareness.

Since 1994, Northrop Grumman DSD's cumulative actions on energy management have reduced its yearly energy demand by 7.7 million kilowatt-hours, producing an annual savings of $600,000 (Figure 2-5). Other projects being explored by the company include co-generation and partnering agreement actions with local utility companies designed to upgrade HVAC systems, minimize front-end investment costs, and maximize recurring energy costs. In 1999, Illinois became a deregulated state for electrical energy. After evaluating numerous electrical energy providers, Northrop Grumman DSD set up a multi-year contract with one provider which saves the site an additional $200,000 annually in electricity costs.

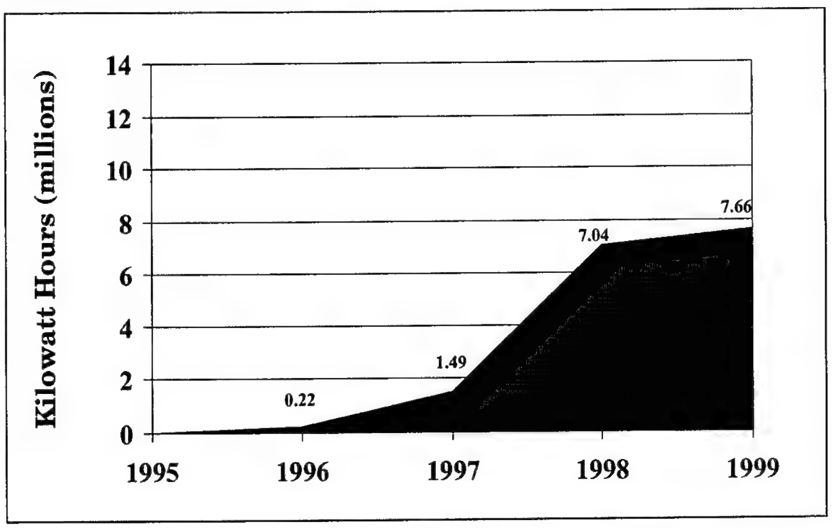


Figure 2-5. Accumulated Yearly Electrical Savings

Facilities Preventive Maintenance System

Prior to 1994, Northrop Grumman DSD's preventive maintenance (P/M) practices involved manually documenting equipment maintenance records on five-by-eight inch cards. This approach was prone to errors as the cards were often misplaced or difficult to locate amongst the thousands of maintenance records. Manufacturers' maintenance recommendations were often unavailable. These factors ultimately resulted in frequent equipment breakdowns and inhibited the ability to quantify operating and replacement costs. To resolve this situation, Northrop Grumman DSD implemented a Facilities P/M system that incorporates manufacturers' maintenance interval recommendations and tracks P/M efforts for all equipment logged into the system.

The Facilities P/M system uses a Maintenance Management System database to automate the process of recording P/M information. The system tracks all maintenance requests for service, enables the scheduling of maintenance based on manufacturers' recommendations, and maintains the maintenance information for use in cost-benefit analyses. Furthermore, the P/M system inherently provides organization for the entire P/M effort at Northrop Grumman DSD.

Since being implemented, the Facilities P/M system has resulted in numerous improvements in Northrop Grumman DSD's P/M practices including accurate records; additional data to support equipment upkeep and replacement actions; improved manpower scheduling; increased equipment life cycles; and reduced maintenance order backlogs. The company estimates its current maintenance costs at 94¢ per square foot. The amount of square feet per maintenance

employee increased from 32,007 in 1995 to 38,708 in 1999, and the percentage of backlogged work orders per month dropped from 19.7% to 0.33%.

Facilities Service Manual

In the past, the limitation of in-house expertise at Northrop Grumman DSD resulted in significant outsourcing of facilities construction projects. Procurement actions were done in a non-competitive manner, while project schedules and costs were loosely monitored during the project's execution. In 1987, the growth of the Rolling Meadows facility necessitated the development of written policies and procedures to govern how in-house construction projects were to be managed. The development of flow processes and process narratives involved cross-functional input from customers, support organizations, and process experts. This two-year endeavor subsequently evolved into Northrop Grumman DSD's Facilities Service Manual (FSM).

The company developed the FSM to aid in controlling facilities construction projects from inception to completion. This manual includes information for all aspects of facilities projects including approved contractor listings for source selection, methods for choosing contractors, approval processes and necessary forms, various flow charts indicating the project process, as well as stipulations for weekly status reports and formal project status meetings with process experts, owners, and stakeholders. The FSM also provides guidelines and direction so process owners, stakeholders, and customers know what to expect and what action is required at every step throughout the process.

The FSM provides Northrop Grumman DSD with a well-defined and consistent approach to facilities construction projects. Since implementing the manual, the company has improved customer satisfaction as high as 97% (based on project feedback) and achieved an annual savings of $200,000 to $300,000 as a result of using competitive bidding procurement practices.

Hazardous Materials Management Program

In the past, Northrop Grumman DSD's method for managing hazardous materials met basic regulatory requirements, but had limited capabilities and minimal employee accessability. This method was also labor-intensive, requiring manual tracking and reporting of various data sources (e.g., procurement records, inventory receipt and distribution records, individual usage records, internal waste disposal records) to obtain a mass-balance of hazardous materials. Although some Material Safety Data Sheets (MSDS) were available on-line, only a limited number of workstations had access to this information. To resolve these issues, Northrop Grumman DSD established the Hazardous Materials Management Program (HMMP).

The HMMP utilizes the Hazardous Materials Manager (HMM), a searchable database and display software package, which provides an integrated and systematic approach to managing hazardous materials activities (e.g., acquisition, day-to-day handling, final disposal, regulatory reporting requirements). HMM is continuously updated and offers on-line accessibility for employees through network computers. Among the information available are MSDS images; digested hazardous information (e.g., carcinogen, mutagen); environmental reporting requirements (e.g., Superfund Amendments and Reauthorization Act [SARA], National Emission Standard for Hazardous Air Pollutants, volatile organic compounds, hazardous air pollutants); specific chemical composition and percentages; and pollution prevention data. The HMMP also uses a paperless inventory tracking system that integrates with the storage tracking automated retrieval system, the company's current method for inventorying its storeroom and production operations.

Additionally, the HMMP provides users with a more cohesive set of tools and information. All site environmental and safety command media that deal with hazardous materials integrate with HMM, as well as the chemical labeling system used to transfer information to secondary containers when repackaging hazardous materials. The command media which document the HMMP (e.g., chemical hazard communication training; flammable and combustible liquids safety; industrial waste management; pollution prevention; spill contingency plan) are readily available throughout the facility via the Intranet website.

The HMMP also captures chemical usage information from the site chemical inventory system, enabling Northrop Grumman DSD to quickly and accurately generate environmental reports. Most importantly, the HMMP allows users to monitor the chemical usage necessary to comply with air permit restrictions and achieve significant pollution prevention efforts. These achievements already include elimination of Class I ozone depleting substances from all manufacturing processes; exemption from SARA reporting in 1997 through 1999; and significant reductions in hazardous waste. Since implementing the HMMP, Northrop Grumman DSD reduced its hazardous waste generation from 492.1 tons in 1989 to 19.8 tons in 1998, a reduction of 96%. In 1999, the company further reduced this figure to 8.2 tons, another 59% reduction compared to the previous year.

Pollution Prevention Program

Northrop Grumman DSD's Pollution Prevention (P2) program evolved from a waste minimization subcommittee initiated by the Environmental, Health, and Safety Management (EHSM) in 1987. In the early days of the program, the company lacked a dedicated budget for capital and expense improvements. P2 projects were proposed to area management, and approvals were based on the availability of labor and funding. Later, the EHSM established a general protocol for reducing hazardous materials usage and waste, and after analyzing the site's chemical usage information, the EHSM planned and coordinated the projects to reduce waste and emissions. Today, Northrop Grumman DSD has taken its P2 program a step further by developing the Annual Environmental Operating Plan (AEOP).

The AEOP integrates the procedures, projects, and goals which make up the P2 strategy. This plan is inclusive and encompasses an array of P2 projects (e.g., bussing, car pooling, energy management, reduction/recycling of materials) used at the facility. To fund these efforts, EHSM submits P2 proposals for Environmental Technical Assistance (ETA) funding. Projects receiving ETA funding are prioritized based on metrics such as hazard levels of chemicals used; size of wastestreams; or highest environmental, regulatory, or contractual impacts. EHSM then gives the P2 project a dedicated source of funding from the ETA pool of funds.

Since implementing the AEOP in its P2 program, Northrop Grumman DSD has significantly decreased its hazardous waste, non-hazardous waste, and air emission pollutants. The company reduced hazardous waste disposal from 492 tons in 1989 to 8.2 tons in 1999; non-hazardous waste disposal from 28 tons in the 1995 to 1997 time frame to 5 tons in 1999; and air emission pollutants from 62.5 tons in 1992 to 13 tons in 1999. Projects which influenced the waste disposal reduction include installation of sludgeless wastewater treatment system for PWB manufacturing; re-evaluation of chemical shelf lives; and recycling of PWB etchant solution. Projects which influenced the air emissions reduction include elimination of Freon from manufacturing processes; conversion of low volatile organic compound paints for manufacturing operations; conversion of Humiseal to a non-regulated conformal coating; and conversion of the degreasing solvent used in the Jetclean machines to a mixture of alcohol and Axarel 2200. The company posts this information on its Intranet website.

Site Recycling Efforts

In the past, non-hazardous waste at Northrop Grumman DSD was not sorted before being hauled away by a trash collector. By allowing recyclable items to be mixed with general waste, the company incurred increased refuse costs and failed in its environmental responsibility to the community. To resolve this situation, the company set up a Recycling program in 1992.

The Recycling program initially focused on white paper which was the simplest and offered the best return for Northrop Grumman DSD. The company instituted this effort incrementally by announcing the program through articles in company-wide flyers and newsletters; providing individual recycling containers at each desk; and placing larger plastic recycling collection containers in high-volume waste areas such as copier machines or reproduction sites. The program expanded when the recycling waste hauler offered to take aluminum cans in the same container as the white paper, as long as the cans were double-bagged. To facilitate this initiative, Northrop Grumman DSD strategically placed aluminum can containers in cafeterias and near vending machines, so that employees would have convenient locations to recycle empty cans. Today, the company has many recycling initiatives including periodicals, newspapers, wooden pallets, toner cartridges, glass and plastic bottles, fluorescent bulbs, and scrap metals.

The company strives to minimize employee effort by enlisting support from its janitorial service contractor. Janitors empty the larger collection bins located throughout the facility and transport the recyclable materials to a single collection point for the recycling waste hauler to collect. This approach increased the company's janitorial contract by only 0.5%. By minimizing the efforts required by the employees to support the Recycling program, Northrop Grumman DSD gets a fairly high level of compliance in return.

Northrop Grumman DSD's direct-rebate savings from the white paper recycling amounted to $5,000 in 1992, reaching a peak of $15,000 in 1996. Although these rebate savings are declining due to falling paper prices, the removal of recyclable items from the general wastestream has produced a 25% reduction in mixed waste pickups. Additionally, the company has increased employee awareness on recycling and fosters environmental responsibility as a member of the community.

Logistics

Excellent Performance Indicators Program

Previously, Northrop Grumman DSD lacked a program related to team training and/or metrics that supported team productivity. In 1992, the company initially set up the Excellent Performance Indicators (EPI) program to encourage problem-solving skills and employee empowerment.

The EPI program has since evolved into an employee empowerment and recognition program based on metrics that measure team performance. The program rewards team accomplishments, provides the necessary tools to monitor data-driven performance, and encourages process improvements directed at reducing costs.

The EPI goals include optimizing employee and team performance; continuous improvement in product quality; and increased sensitivity to internal and external customer/supplier relationships through employee involvement. Areas of operations are organized into zones (e.g., microelectronics, CCA fabrication, stores) where specific metrics are applied. Members of a zone include all levels of departmental job functions (e.g., technicians, engineers, inspectors, dispatchers). In addition, key performance indicators are specified based on the operations completed in each zone.

The EPI metric structure is a flexible measurement system that can accommodate multiple programs and processes. This on-line, data-reporting system operates as the basis for measurement. Data is provided on a weekly basis so the company can target possible areas for improvement, and teams are formed to address manufacturing issues (e.g., improvements, savings, training, communications). The EPI program focuses on accomplishments and improvements achieved on a quarterly and yearly basis. An award ceremony is held quarterly to recognize zones that have achieved their goals as well as special acknowledgment to those which are close. Each member of a winning zone is eligible for a monetary award.

Another aspect of the EPI program is training; some of which enhance employees' educational needs while others target skills such as problem solving, effect and manage change, team building, and communications. Northrop Grumman DSD also uses Flip Flops, modules that create training scenarios for employees such as running a production line to achieve customer satisfaction (Lego® creations); learning to comprehend the overall picture (Purple Spot); dealing with obstacles to achieve a goal (Gold of the Desert King); and identifying how lean initiatives currently relate to existing business processes (Learning to Learn). Training is a motivational factor that generates enthusiasm and provides a foundation for the success of the EPI program.

EPI provides Northrop Grumman DSD with tools to monitor and improve performance for all programs. The result is reduced rework and increased efficiency. For long-term programs, the company improved its efficiency from 87% (baseline) in 1992 to 99.1% in 1997. In addition, the EPI program's training enhances employee self-esteem and motivation, empowers them to improve processes, and fosters communication with management.

Management

Commodity Design Teams

New business growth is an enterprise goal of Northrop Grumman DSD. The company recognizes that the penetration and/or expansion of new markets not only require the making of significant reductions in material, assembly, and test costs, but also the understanding and managing of the entire value stream for the design-to-manufacturing transition. Essential to this process is leveraging the knowledge, technology, and resources of all team members including key suppliers. In June 1999, Northrop Grumman DSD developed and applied its Commodity Design Team process to penetrate the MPM commodity market. The traveling wave tube (TWT), a main critical MPM assembly, was chosen for this effort.

The Commodity Design Team's goal was to achieve a 30% to 60% reduction in costs through material, technical, and process change recommendations and increased volume buys. The cross-functional team first identified best practices, suppliers, products, and industry benchmarks. Next, they performed a series of analyses and evaluations of materials, components, and subassemblies with the goal of meeting predetermined cost reductions that would allow market penetration. A critical part of the Commodity Design Team process was to identify and work jointly with key suppliers that could significantly contribute to this common goal. These suppliers attended a one-day technical conference involving market overview and individual supplier breakout sessions. There, suppliers identified strengths and weaknesses in dealing with Northrop Grumman DSD. Tours of the assembly and test areas were conducted to show suppliers their product applications and the processes used to manufacture final products. The Commodity Design Team also worked with piece part drawings and assemblies to identify potential areas for improving cost and cycle time. All team members provided open and honest feedback.

The TWT Commodity Design Team achieved their goal with an overall material cost reduction of 39%. The process also produced a 200% increase in work flow velocity and a 30% reduction in inventory. Contributors to this success include reviewing and understanding the key attributes or product characteristics; conceptualizing methods that attack key cost drivers; and establishing an effective working relationship with suppliers. The Commodity Design Team process strives to create a win-win situation by driving down costs while maintaining an equivalent or higher profitability throughout the value chain. As a result, the Commodity Design Team was able to focus Northrop Grumman DSD and its key suppliers toward a common

vision and set of objectives by leveraging their combined knowledge, technology, facilities, and purchasing power. With this success, the team is now formalizing this process for application to other commodity markets including the remaining areas of MPM: integrated power conditioners and solid state amplifiers.

Integrated Management Control System

Previously, Northrop Grumman DSD used a manual, paper-intensive system for requirements planning, inventory control, purchase orders, requisitions, and shop floor management. In 1974, the company implemented an enterprise-wide, paperless system for Manufacturing Resource Planning (MRP II), known internally as the Integrated Management Control System (IMCS). IMCS is designed to synchronize production and delivery throughout the value chain.

IMCS (Figure 2-6) is a hybrid collection of integrated, high-end, commercially-available software which Northrop Grumman DSD tailored to its unique management and customer requirements. With its closed-loop MRP features, IMCS implements just-in-time (JIT) policies that automate tools to establish and monitor planning, program performance, material management, supplier management, shop floor, capacity planning, and financial activities. IMCS also has key capabilities to communicate electronically to customers and suppliers. Electronic commerce methods include electronic data interchange (EDI), electronic data faxing, e-mail, and file transfer protocols.

The planning system modules within IMCS are the front and back ends of the MRP II process. The system establishes and tracks the Master Sales Plan to meet the contract requirements; the Master Production Schedule for manufacturing shop orders; and Material Requirements Plan to ensure that program objectives and schedule deliveries are met on time. Full visibility, accountability, and performance are provided within the system for closed-loop planning and decision making. Key subsystems within IMCS include:

- The Automated Customer Order Tracking System (ACOTS) is a full contract entry and tracking system

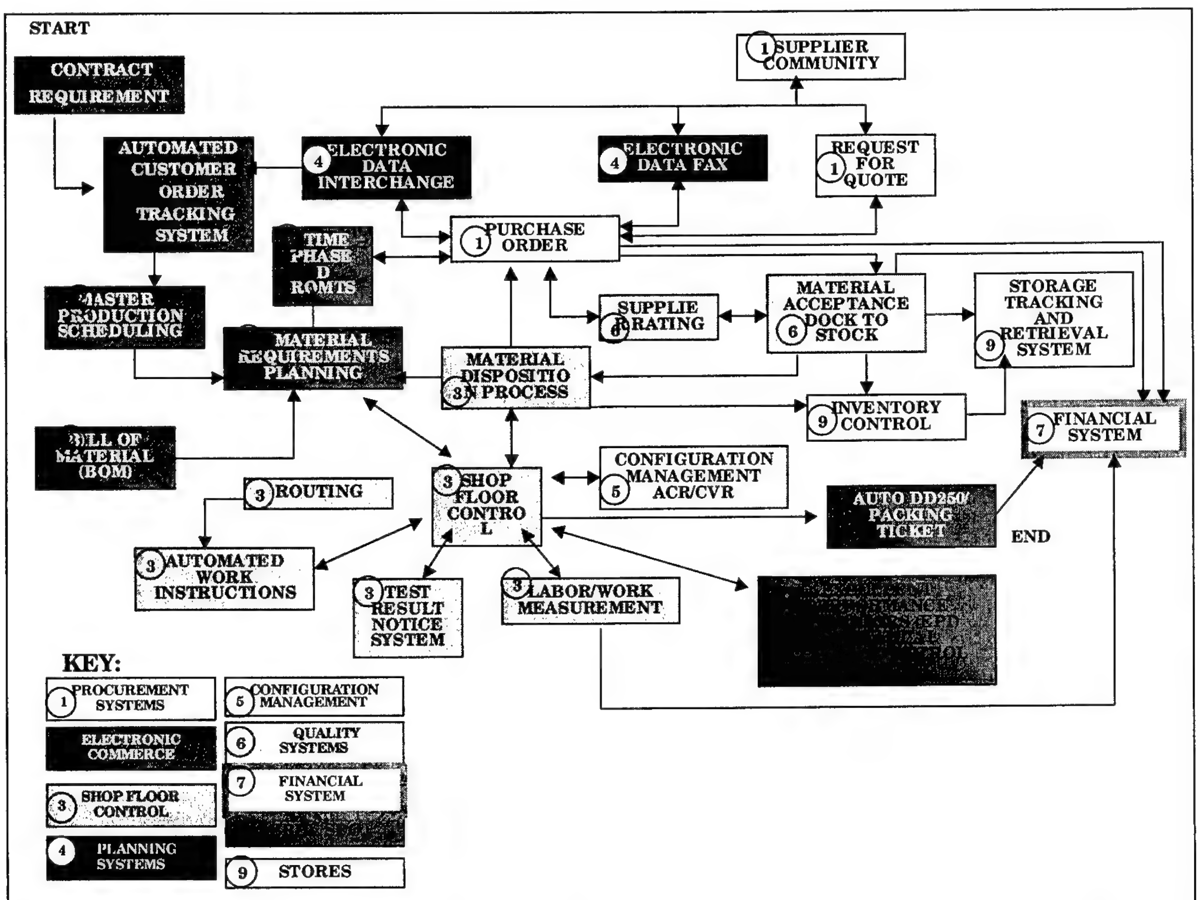


Figure 2-6. Integrated Management Control System

which provides electronic notification of new and modified contract activities. Implemented in 1995, ACOTS drives the Master Production Schedule and automates the invoice process via EDI with the customer. The contract performance tracking system has automated signature approval, generation of packing tickets, and warning of contract delinquencies. The system processes over 10,000 transactions per month, and has reduced the sell-off/shipment process by 64%.

- Bills of Material can automatically be converted from an Engineering Bill of Material to a Manufacturing Bill of Material (MBOM) from any file format to the mainframe. Mass change updates, as well as date effectivity are also permitted. This module allows the MBOM to be used as the basis for MRP while achieving a very high accuracy rate as required for the government's MMAS.
- MRP systems create time-phased material requirements with automated weekly schedule and requirement adjustments to ensure that supply equals demand. These systems also perform capacity planning simulation to ensure critical path parts and material availability are identified, and to optimize the plan to meet the schedule. An MRP system focused at the parts' levels enabled Northrop Grumman DSD to reduce its total lead time by more than 70% since 1996.
- The AutoBuy module, part of the IMCS procurement subsystem, automatically generates requisitions for requirements, approves requisitions based on set criteria, and creates purchase orders for master agreement parts. The module also eliminates manual order entry for repetitive buys. Key to the success of AutoBuy is the Procurement Master Agreements which can reduce cycle time by seven weeks. By using this system, Northrop Grumman DSD has reduced quote cycle time to zero days for more than 25% of its hardware line items.
- The IMCS Material Pooling provides the capability for combining inventory tasks based on defined objectives (e.g., requirements, cost, location, usage). Cost savings are achieved by reducing the required storage space; material handling and picking cycle times; and incoming inspection lots. Additionally, this system decreases the handling of multiple receipts; controls the inventory transfer process; improves the efficiency of requisition and purchase orders; and reduces supplier expediting and schedule change notification activities. By using Material Pooling, Northrop Grumman DSD reduced the planning analysis for introducing new jobs from four weeks to one. The overall pooling savings provided approximately 6% of the total overhead savings.
- The Storage Tracking Automated Retrieval System (STARS) is an inventory system that provides on-line, real-time transaction processing. Parts are stored and retrieved in horizontal and vertical carousels which utilize barcode technology and automated trackbots. STARS features first-in-first-out logic, lot control, serialization, visibility of shelf life, product by program, and off-site stock locations. By being integrated with the IMCS Shop Floor Control System, STARS can pick parts to the latest MBOM or other requirement. Shop orders released, based on the MRP JIT release date, initiate the automated STARS to pick the shop order components.
- The IMCS Shop Floor Control System modules operate as an integrated, on-line, real-time system that tracks hardware, sets priorities, and generates routings. Controlled, detailed work instructions (available on-line) provide the system with manual, semi-automated, and automated operations. These instruction packages include drawing and procedure references; parts, bin, and tool lists; manufacturing order traveler sequences, and visual aids. Labor information and work measurement are collected electronically at the workstation for use by management and the Finance Department. The IMCS Shop Floor Control System also uses Statistical Process Control (SPC) with on-line data analysis graphical interfaces.
- Test Result Notices (TRNs) are a key element of Northrop Grumman DSD's functional test capability, providing on-line, real-time data collection and analysis capabilities. The TRN system allows chain-up/chain-down linkage between assembly numbers, and permits the issuance of TRNs for multiple assemblies at once. Failure thresholds and integrated corrective actions (both process and supplier) are also part of the TRN system. As a result, abnormal conditions are immediately recognized and special causes of variation are investigated and eliminated.

Since implementing the IMCS integration, Northrop Grumman DSD reduced support costs by 50%; increased transactions by four-fold; held early deliveries of purchase orders to less than 1%; and processed purchased orders to stock at more than 80%. The reduction in manufacturing risk has also enabled the company to meet on-time contractual deliveries for more than 65 consecutive months on the AN/ALQ-135 program. IMCS has been rated green and compliant under the MMAS since 1991, and has received the Computer-Aided Acquisition & Logistics Support's Electronic Commerce Award in 1996.

ISO-9001 Quality Management System Audit

In the past, Northrop Grumman DSD used separate auditing systems for its ISO-9001, process, and software audits. This approach resulted in more than 50% duplica-

tion as these systems covered overlapping areas. The manual method for tracking corrective actions was also lengthy and ineffective. Management had low visibility of the overall quality management status, and the use of a general ISO-9001 audit checklist was not always relative to Northrop Grumman DSD's business. In 1999, the company consolidated all of these individual systems into the ISO-9001 Quality Management System Audit.

The ISO-9001 Quality Management System Audit combines the ISO-9001 20 elements, the ISO TickIT software, and the process audits into one management reporting system. The system also uses a singular electronic data system for auditing, and consolidates the audit planning activities. As a result, duplication is eliminated and corrective actions are easily tracked. Audit records include favorable and unfavorable audit results; corrective action results (CARs); and delinquent CARs. Overdue corrective actions for audits are automatically escalated to consecutively higher levels of management in one week increments on a monthly basis.

In 1999, Northrop Grumman DSD also established the ISO-9001 Annual Quality Management System Health Status. Provided to management, this annual report covers the overall ISO-9001 health assessment, current audit results, a three-year audit summary, recommended changes to the Quality Management System, customer satisfaction, and other audit topics.

Together, the ISO-9001 Quality Management System Audit and the ISO-9001 Annual Quality Management System Health Status provides Northrop Grumman DSD with greater visibility and access to audit results. By using an efficient, consolidated system, the company decreased the number of audits from 268 in 1998 to 183 in 1999, a reduction of 32%. In 2000, this figure was further reduced by another 16%. Corrective action cycle times have also improved. Previously, more than 10% of the corrective actions were late or rescheduled. That statistic is now less than 2%.

Modular Factory for Electronic Warfare Component Manufacturing

Northrop Grumman DSD recognizes that the business strategies used by the defense industry in the 1980s and early 1990s are no longer feasible today. Over the years, declining national defense spending has reduced the funding available to support military electronics and inevitably eroded the supplier industrial base. Despite this trend, customer demand for higher quality products and advancements in electronic warfare technologies continues to grow. To remain competitive, the defense industry needed to adopt a new strategy that strived for a flexible, lean infrastructure. Initiated in 1996, the Modular Factory for Electronic Warfare Component Manufacturing (MFEWCM) program is a joint DOD-Northrop Grumman DSD vision to address the needs of the evolving electronic warfare market. The program's goals are to achieve market-driven products, faster product development, reduced product cost, simplified product design, and market leverage through functionality and manufacturability.

To accomplish these goals, MFEWCM identifies, adopts, verifies, and integrates practices which not only drive for leanness and flexibility throughout the value chain, but also become integral constituents of an infrastructure to promote future changes. The Lean Aerospace Initiative (LAI) developed the groundwork within its Factory of Operations Focus Group in terms of identifying overarching/enabling practices and measures of lean principles. LAI is a joint industry, academia, labor, and government consortium lead by the Massachusetts Institute of Technology to evaluate the implications of adapting lean production principles to the aerospace industry. In this case, the MFEWCM program is a case study that will validate the modular factory in a defense electronics environment. The MFEWCM initiative is a three-phase approach to use lean practices and develop a quantity-independent, flexible manufacturing capability for cost-effective MPMs.

Phase I (Pathfinder Effort) was a $2.4 million, 18-month cooperative agreement with the U.S. Air Force Research Laboratory to lay the foundation for the lean, flexible modular factory and institute the business practices they entail. During this phase, a seamless, closed-loop, integrated information infrastructure was established using several enabling technologies. A commercial-off-the-shelf (COTS) Product Data Management software application (Metaphase II) was customized to include an intelligent part library and a cost model algorithm. This application manages all product-related information (e.g., schedule, life cycle data, change management) and has been successfully used on the B-2 Bomber and the Joint Strike Fighter programs. An automated Design Rule Checker was also implemented to replace manual design reviews. The Automated Equipment Interface (AEI) provides designers with a design translator so they can convert designs into formats recognized by product equipment, eliminating the need for manual equipment programming after production release. The AEI also provides an operator interface. The interface is the key process that will prove-out the seamless transition between design and production. A Manufacturing Execution System monitors the equipment status and notifies personnel when series out-of-control conditions (e.g., wirebonder stage overheating) occur.

A 750-square foot section of Northrop Grumman DSD's microelectronics manufacturing facility was reconfigured

into a modular cell (Figure 2-7), which shifted the focus from process-oriented to flexible, product-oriented, demand-driven manufacturing. An activity-based cost accounting system was uniquely tailored to track savings associated with eliminating non-value-added tasks. The existing design cycle and pilot production run were then baselined. The preliminary production applications reduced machine setup (changeover/programming) by more than 90% and decreased machine run (recurring) times by up to 50%.

Phase II (Pilot Implementation) was a $2 million, 30-month Joint Service effort with the Naval Research Laboratory/SPAWAR to design and produce C-Band MPMs for the U.S. Navy Cooperative Engagement Capability program. This phase measured the factory's performance improvements against the Phase I baseline. The result was a 20% reduction in design cost; a 30% reduction in inventory cost; a 40% reduction in design cycle time; a 40% reduction in hybrid (microelectronics) manufacturing costs; a 60% reduction in manufacturing cycle time; a 200% increase in work flow velocity; and a 100% increase in shop floor density.

The current Phase III (Extension or Scale-up/Out Program) focuses on extending these practices throughout Northrop Grumman DSD's electronics components manufacturing activities. The final report will provide a summary of achievements and lessons learned in establishing a lean, flexible modular factory under the MFEWCM program. Particular emphasis will be on the applicability and results of extending these efforts and enabling practices/ technologies.

Process Oriented Contract Administration Services

In June 1992, Northrop Grumman DSD and the Defense Contracts Management Agency (DCMA) set up a government initiative known as the Process Oriented Contract Administration Services (PROCAS). This relationship is mutually beneficial and unique in industry. Prior to the PROCAS initiative, few formal contractor/customer mechanisms existed to address problems, resolve issues, or facilitate improvement initiatives. PROCAS uses a robust team effort to ensure quality products, improve communications, and develop consistent processes. PROCAS teams develop process improvements which are beneficial to both participants, monitor progress, and provide status and visibility.

New and revised government regulations, changing standards, antiquated specifications, and a dynamic defense environment constantly present new challenges for Northrop Grumman DSD and DCMA. To deal with these challenges, PROCAS teams address current issues, management processes and systems, production processing, and specific hardware issues. To date, eight teams have completed their tasks and progressed to the adjusted management stage. Among them are Calibration Conversion, Subcontract Flowdown, Electron Tube Process, and Inspection & Test. Four team are currently active at Northrop Grumman DSD: On Time Delivery, Final Overhead Rates, Earned Value Management System, and ISO-9000 Conversion.

In addition to the team efforts, Oversight and Management Council monthly meetings are held to monitor the organizational status. Quarterly status briefings for management and weekly team action meetings round out the process into an effective management tool. PROCAS provides many benefits to Northrop Grumman DSD and its customers including enhanced communications, mutual respect, consensus priorities for improvement initiatives, and significant savings and achievements from PROCAS efforts and SPIs. The PROCAS initiative also fosters DCMA's confidence in Northrop Grumman DSD's systems, and is a factor that allowed them to discontinue the in-process inspection and hardware acceptance based on that confidence. In turn, Northrop Grumman DSD is able to

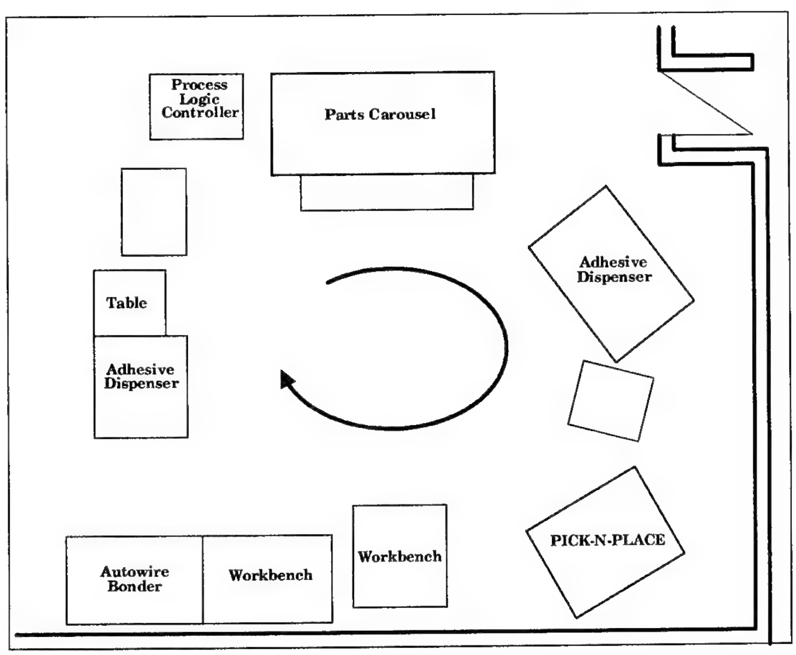


Figure 2-7. Modular Factory

quickly move hardware through the production process without awaiting DCMA's review and approval.

Product Assurance Reporting and Trending System

Prior to 1995, each organization at Northrop Grumman DSD maintained its own stand-alone database for nonconforming material reports (NMRs); stocksweep generation and tracking; depot field return data; Test Result Notices; and Material Exceptions. The corrective action systems, including the trending of failure data and corrective actions, were also managed in separate manual data systems. Cross-platform comunication was limited because the databases operated in different software applications. In addition, approximately 32% duplication occurred across all the systems. Northrop Grumman DSD implemented the Product Assurance Reporting and Trending System (P.A.R.T.S) to enhance its operations by consolidating the stand-alone systems into a single integrated database (Figure 2-8).

The five database entities were integrated into a single client/server database which operates on a common SQL and application software. Other systems added to this consolidated database include corrective action requests and ISO, process, and software assessments. The P.A.R.T.S database standardizes data for NMRs and corrective actions; provides consistent, reliable historical data; and is easily modified for changing system and site requirements. In addition, trending capabilities have improved and users can generate various reports including ones that show visible process bottlenecks. Outputs from this system include cycle time reports, corrective action board reports, NMR reports, and return material authorizations. All organizations at Northrop Grumman DSD have on-line access to the P.A.R.T.S database.

P.A.R.T.S enabled Northrop Grumman DSD to reduce its system support costs by combining databases, minimizing manual entry, using a single software solution, improving process flows, and decreasing reproduction costs through

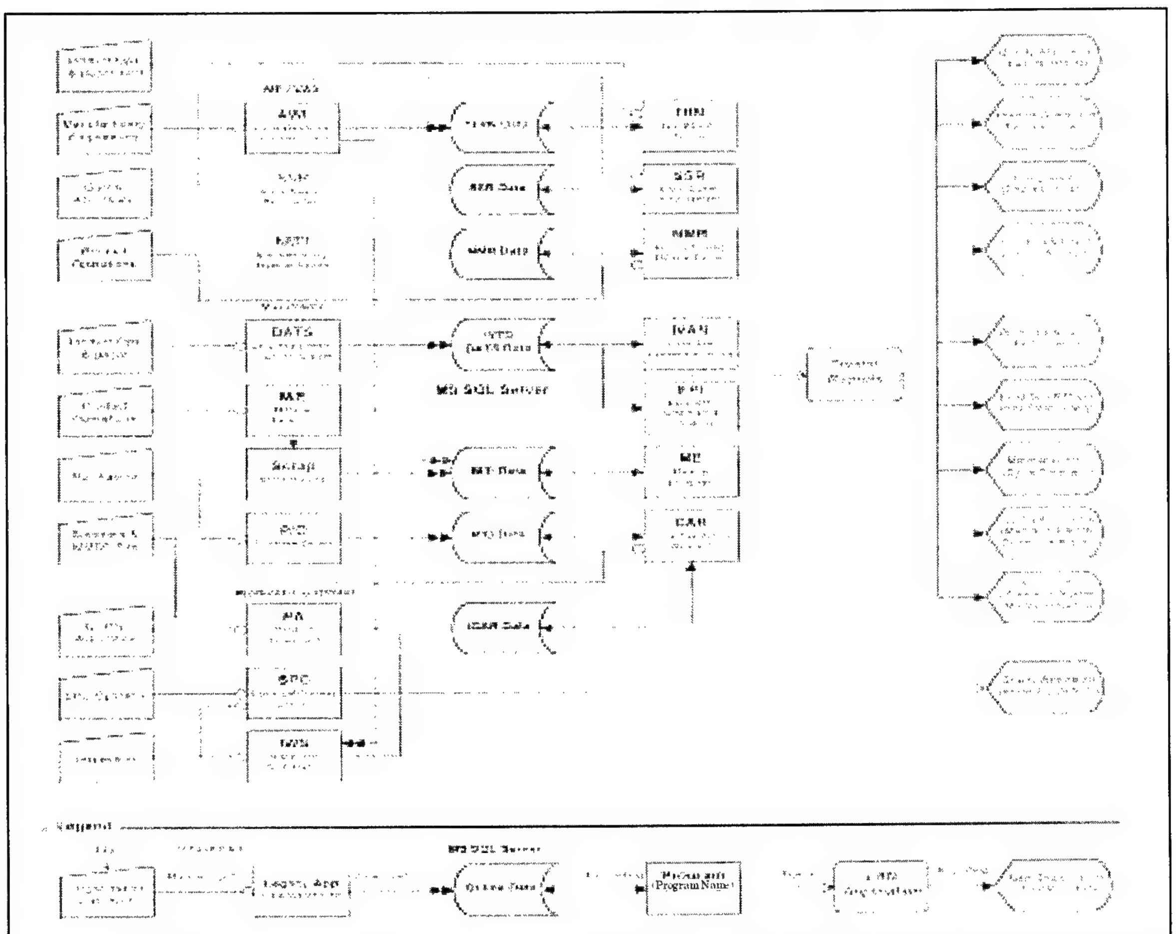


Figure 2-8. Product Assurance Reporting and Trending System

electronic distribution of data and reports. The company realized a 32% reduction in redundant data, a 30% reduction in manual entry, and a 36% reduction in maintenance tables.

Proposal Cost Estimating Relationships

Prior to 1992, Northrop Grumman DSD utilized bottoms-up discrete estimates for proposal cost estimating. This practice employed multiple estimators for related but dissimilar tasks, as well as different data sources without explanation. The submitted proposals were inconsistent, voluminous, and difficult to understand. As a result, customers questioned the cost estimates generated in this manner which significantly reduced Northrop Grumman DSD's position in pricing negotiations. To establish a more consistent pricing methodology, the company developed Proposal Cost Estimating Relationships (CERs) which generate reliable estimates in a timely manner with nearly zero loss in negotiation.

CERs significantly reduce routine proposal preparation costs normally involved in the costing/pricing process. This practice utilizes one or more independent variables (e.g., production assembly/test hours, production material cost) to estimate the dependent variable in a proposal effort. A CER is established through a statistical analysis of historical data. Once established, the independent variable is estimated and inserted into the CER equation. A dependent variable, such as hours or another direct cost element, is then automatically generated. The process effectively creates a template for cost estimating, which enables Northrop Grumman DSD to apply it to many individual contract actions. The result is a shortened negotiation process; more consistent and easily analyzed data; and a customer who is satisfied with the process and estimates.

Various statistical methods can be used such as simple or rolling averages, single variable linear regressions, and multiple variant/non-linear equations. Critical data should include:

- Multiple data points to generate accurate analysis. A larger collection of cost data usually produces more accurate results.
- Stability in the product, processes, and environment. Over time, changes in these areas may yield inconclusive analysis and/or unpredictable results.
- Logical relationships between the dependent and independent variables to avoid statistical anomalies.

Northrop Grumman DSD's Proposal CERs use a well-defined process to generate consistent pricing in proposal negotiations. This process also enables the company to lower negotiation losses to nearly zero, save a significant amount in bid and proposal labor, achieve a 98% on-time proposal rate, and foster a goodwill relationship with its customers. Because CERs are generated with Defense Contractor Audit Agency software, the data is easily transmitted and understood by all involved. The Proposal CERs foster a better sharing of cost estimating data as well as enlighten customers on new tools and techniques.

Rolling Forecast System

In the past, Northrop Grumman DSD's method for forecasting acquisitions involved an undocumented, manually-intensive informal process which used a single-user Paradox system. This system was infrequently updated, had limited hard-copy report distribution, was independent of other planning systems, and did not operate in real time. The need to revise this process became more apparent in the early 1990s as Northrop Grumman DSD migrated from a single-product dominated facility to a multi-program plant. As a result, the company developed the Rolling Forecast system which forecasts new business and funding acquisitions for long- and short-range business planning activities. Forecast data is used in planning rates and manpower, and provides critical input into Northrop Grumman DSD's Sector Long Range Strategic Plan and Annual Operating Plan.

From 1992 to 1994, Northrop Grumman DSD developed, documented, implemented, and tested an initial version of its forecasting system. The need for automation was then recognized. Beginning in 1995, the company developed system and software requirements for its forecasting system, tested COTS products, and finally decided to develop its own unique software application package. A contract was issued to Metamor Technologies, Ltd. for software development with the support and contribution of Northrop Grumman DSD's in-house software developers. As a result, all improvements and revisions to the database are now completed on-site by Northrop Grumman DSD. The Rolling Forecast system was launched in December 1996, along with intensive user training.

The Rolling Forecast system tracks activities across all product lines and market segments from initial concept exploration through post-production support. Every forecast entry in the system is assigned a probability of *go* and a probability of *win*. Under this methodology, all acquisitions are included in the portfolio at the corresponding weighted value. Features of the Rolling Forecast system include a multi-user Windows-based platform, a standardized view and control of data for all product lines, system security, on-line approval, flexibility, real-time capability, extended search options, and expanded capability to manipulate data within the database. Program Management,

Business Management, and Business Development generate the data, and Business Development manages the process.

When a business opportunity is entered into the database, a unique rolling forecast identification number is generated. User access and privileges, as well as code table maintenance, are controlled by Business Development through the system administration functions within the application. Formal system updates are conducted at least two times a year, and updates to the current year are done monthly. Users and management are able to access acquisition data and other relevant information such as customer, contract type, description, key milestones, status, and program phase. The Rolling Forecast system can generate 26 parameterized standard reports in full or factored dollars. Furthermore, information contained within the database can be exported into Microsoft Word, Excel, or Access, and e-mailed as Rich Text Format. A web-based, on-line help system has also been implemented to support the forecasting system.

Northrop Grumman DSD's Rolling Forecast system provides documented policies and procedures, and a process for continuous improvement. Since implementing this system, the company's forecast accuracy continues to improve. The mid-year indicated final projection for 1999 was within 1% of the actual year-end number. The key to the Rolling Forecast system is its flexibility within the constantly evolving business environment. The user-friendly database provides real-time database provides real-time data to users and management; standardizes data; and tracks progress of opportunity throughout the entire process.

Security Education and Ethics Awareness Committee

Prior to 1995, Northrop Grumman DSD's security education and ethics awareness were handled by two independent committees, respectively. Aside from the different subject matters, both committees followed similar lines of action and disseminated information through annual mass briefings. However, this approach generated redundancies in effort and cost. To resolve the situation, Northrop Grumman DSD merged the two groups and created the Security Education and Ethics Awareness Committee (SEEAC). SEEAC is a formally chartered committee with a precise structure, operating guidelines, and a mission statement: education instead of punishment.

SEEAC provides, conducts, and sponsors security education and ethics awareness activities so that employees are aware of and comply with corporate, sector, division, government, and customer requirements. The cross-functional committee is composed of employees from various business elements including Security, Engineering, Business Management, and Operations. The integrated team approach enables SEEAC to reach all employees with the greatest possible impact. SEEAC uses various publication sources (e.g., *Security Awareness Program*, *Northrop Grumman News*, Intranet website) as well as awareness events to communicate information to employees. The annual Security/Ethics Awareness Week features a Security and Ethics Challenge contest that quizzes employees on their security and ethics knowledge in a game-show format. SEEAC's efforts lend visibility; demonstrate a serious corporate commitment to security and ethics; and address emerging issues with broad dissemination. Government representatives, as well as Northrop Grumman DSD management, favorably view the SEEAC approach and subsequent benefits.

The success of SEEAC demonstrates Northrop Grumman DSD's strong commitment to security education and ethics awareness among personnel. Defense Security Services' audits have shown an 18% improvement in security discrepancies to a low of 2%. In 1997, Northrop Grumman DSD received the James S. Cogswell Award for Industrial Security Excellence. SEEAC's performance and impact were credited as contributing factors to this achievement.

Security Safety Inspection Program

Previously at Northrop Grumman DSD, Security performed fire rounds, perimeter checks, and fire alarm tests. Although Security frequently discovered safety discrepancies, the company lacked standardized documentation for these occurrences. Environmental inspections were only performed to meet regulatory compliance, and safety inspections were conducted only as issues were identified. In 1992, Northrop Grumman DSD altered its reactive approach by creating the Security Safety Inspection Program (SSIP). This program collaborates the efforts of Security and the EHSM.

SSIP is a proactive approach to environmental and safety compliance inspections. EHSM trains security officers to perform visual inspections based on environmental and safety fundamentals and the basics of government and state regulations. This arrangement fosters effective use of existing personnel and takes advantage of Security's access to the entire facility. The facility is mapped into 30 zones with two inspections per zone. Each shift performs its own inspections, resulting in continuous inspections 24 hours a day, 365 days per year. Security enters inspection results into the SSIP database which records, issues, and tracks all safety findings. The database automatically generates findings as formal memos to responsible parties, and incor-

porates the responses and corrective actions to close out the findings. The SSIP database is also used to identify metrics and trends for discussion at monthly Environmental, Health, and Safety Council and Committee meetings. Monthly safety reports are generated and disseminated to organizational area management and used for employee training and process improvement.

SSIP enables Northrop Grumman DSD to create an environment of safety awareness and compliance throughout its facility, as well as reduce workplace hazards. Since 1992, the company's injury rate has decreased by 40%. Northrop Grumman DSD's injury rate is one-fourth that of the electronics industry.

Supplier Teaming

Previously, Northrop Grumman DSD's primary communications with suppliers involved either negotiating new business or visiting them when schedule/performance issues occurred. Products were designed without supplier input, and issues were traditionally resolved within the company. Business continued in this manner until 1993 when Northrop Grumman DSD conducted a feedback survey with its 700 suppliers. The survey results rated the company as a below average customer. Suppliers' concerns included lack of trust, loyalty to good suppliers, emphasis on low price versus total incurred cost, lack of supplier involvement in design, and scheduling issues. To improve its relationship with suppliers, Northrop Grumman DSD began developing a multi-faceted Supplier Management System which became fully implemented in 1996.

One element of the Supplier Management System is the Supplier Certification (or Vision) program, which highlights key suppliers from various product disciplines. Through the Vision program, Northrop Grumman DSD teams with suppliers to establish performance characteristics of materials and services; utilizes their engineering and technical resources to develop or improve products; and helps leverage new programs and business opportunities. The Vision program also recognizes top performing suppliers. Northrop Grumman DSD awards gold, silver, and bronze status to suppliers who meet award criteria in performance, advanced quality practices, and business assessment. The company may further reward a supplier who achieves a gold award by waiving incoming inspections or extra documentation.

Procurement, Engineering, and QA nominate suppliers under the Supplier Management System. Meetings are held with these suppliers to discuss inclusion into the program and to identify key areas for improvement. Procurement and QA representatives are responsible for working with suppliers to resolve performance issues and address actions generated by the Supplier/Northrop Grumman DSD team. Suppliers may propose design, test, data, and quality initiatives that will improve products and/or reduce costs. The process features technology transfers, and minimizes inspection, test, and data requirements to the suppliers. Another aspect of the Supplier Management System is the involvement of Northrop Grumman DSD's top management. The Vice President of Program Management and other top managers personally visit suppliers' sites to foster communications and discuss performance status. Northrop Grumman DSD also shares corporate goals and strategic plans with its suppliers, enabling them to plan future business endeavors with the company.

Through the Supplier Management System, Northrop Grumman DSD has established good working relationships with its suppliers. As a result, suppliers are more willing to invest in new equipment and share technology. Suppliers have also benefitted from long-term agreements; involvement in product design; reduced inspection, test, and data requirements; and consideration on future procurements. Likewise, Northrop Grumman DSD's benefits include lowered costs, improved quality, decreased time to market, and increased technical resources. The Supplier Management System has been a factor in reducing the company's overall manufacturing cycle time (from order placement to product ship out) by 62%.

Wellness Program

Prior to 1992, Northrop Grumman DSD did not have a proactive wellness program. Instead, the nursing staff provided blood pressure readings; weight management; basic information on nutrition and diseases; and health advice to employees in an informal manner. In 1992, the company migrated to a comprehensive wellness program, known as HealthWaves, as a proactive solution to employee health needs.

HealthWaves provides employees with a part-time professional health representative on-site; extensive wellness services such as books and videos; monthly health discussion groups and seminars; a monthly newsletter via e-mail; and exercise classes. Northrop Grumman DSD enhances this program by offering its employees an array of wellness tools. Among these are a searchable software database for health information; periodic health fairs; annual blood screening for employees, employee spouses, and retirees; and an annual flu immunization program. HealthWaves is designed to promote employee health and fitness, which is achieved through basic services (e.g., blood pressure checks, body fat calculations) as well as fitness classes and educational seminars (e.g., breast cancer, high blood pressure, heart disease). Additionally, Northrop Grumman DSD has

set up a HealthWaves website to provide health and fitness information to its employees.

Proactive worksite wellness programs have proven to reduce insurance expenses by identifying health issues early, when still treatable. Northrop Grumman DSD sponsors an Annual Blood Screen Day, which is an opportunity for employees to have their blood tested for various illnesses and conditions including liver dysfunction, abnormal cholesterol readings, and high risk for heart disease. During Year 2000 Blood Screening Day, 40% of Northrop Grumman DSD's employees took advantage of the program. Of these, 20.9% of the participants were identified with atypical test results. Two individuals tested positive for cancer, and are now undergoing treatment. HealthWaves fosters employee morale, health, productivity, and attendance at Northrop Grumman DSD.

Section 3

Information

Design

Product Data Manager Design Enabler

In 1996, Northrop Grumman DSD, in collaboration with MANTECH, began a cost-sharing initiative to provide a virtual environment for managing the product development life cycles/processes. The system implementation, expected to be completed in 2001, is already providing design and testing capabilities for a selected pilot project. Product Data Management (PDM) is an integrated system used to manage product data throughout its life cycle; enables collaboration early in the life cycle; distributes data automatically to functions when needed; and controls product data through vaulting.

PDM was customized and implemented into the MFEWCM limited environment, and later developed into a fully vertically integrated system. From there, the company initiated a pilot program; acquired software licenses; implemented system enhancements; trained personnel; and established concurrent engineering procedures. These efforts helped establish PDM as the routine method for conducting business in current and future programs. PDM also features a single repository for all product data (e.g., manufacturing process documents, tooling drawings) to support the environment at Northrop Grumman DSD.

A key element of design is the intelligent selection of components which operates in conjunction with PDM. Here, tools are selected and developed to consolidate part numbers, as well as control the proliferation of part numbers that have resulted over the years from multiple design authorities, plant consolidations, and transitions. To improve component selection, a Preferred Parts List with searchable attributes will be implemented on the site command media web with subsequent integration into CAD design systems and PDM. Also, a contractor has been retained to provide integrated supplier catalog capabilities, verify component life cycles, and manage part families for optimization (e.g., component price, delivery, quality).

Test

Built-In-Test

Northrop Grumman DSD is a leader in Built-In-Test (BIT) design and implementation. Traditional BITs are relatively effective for systems built in the last 15 years, but they tend to be primitive, inadequate, and unreliable. As military flight hardware becomes more sophisticated, BITs must be able to provide mission-oriented information (e.g., system readiness, functional failure, failure criticality, capability remaining), as well as maintenance-oriented information (system operational status, fault detection and isolation, storage of test data, verification of repairs). In response, Northrop Grumman DSD has developed a new process for BITs.

The company also wanted its revised BIT process to use less test equipment, reduce test and repair times, and minimize operator skill level. Several of Northrop Grumman DSD's aircraft electronic warfare systems now require no-flight line test equipment. The company's revised BIT process includes a Diagnostic Knowledge Base (DKB) which is implemented on a PCMCIA card. The DKB can quickly and completely isolate failures in complex military systems to a one-line replaceable unit by using the functional element testing concept. BIT information can also be revised and updated through the DKB.

Northrop Grumman's BIT process is quick, reliable, simple, and cost effective. Benefits include rapid testing (30 seconds to two minutes); significant reduction of false alarms and pulls; operational by a low-skill, one-person interface; automatic fault detection and isolation; and less support equipment and training requirements. The BIT log data can also provide additional information, enabling the user to understand the condition. The DKB can be downloaded or updated independently of the aircraft's Operational Flight Program.

Environmental Industrial Test

Environmental testing at Northrop Grumman DSD is used to simulate and evaluate the effects of vibration, temperature, stress, altitude, shock, humidity, and corrosion. In 1995, the company added industrial testing to its services. While these capabilities were all initially developed to support military products, they were recently expanded to include commercial clientele. The commercial client services now amount to approximately 25% of the system's capacity. The range of commercial clients include aircraft, industrial electronics, industrial electrical, consumer electronics, and the automotive industries.

Northrop Grumman DSD's partnerships with commercial industry has brought professional as well as business progress. The company has implemented improved test documentation, maintenance scheduling, and formal equip-

ment procedures to achieve full commercial accreditation levels. These improvements have been attested via ISO certifications and by the American Association for Laboratory Accreditation. The accreditations also include a variety of electrical and chemical tests and analyses.

Not only have Northrop Grumman DSD's services been improved through commercial exposure, but they have also contributed as unique independent testing capabilities to customers in the Chicago region. Industrial testing fills the gaps in work schedules, improves cash flow, and cuts overhead expenses by providing additional contract work for non-traditional customers. Additional details are available on the company's website at http://sensor.northgrum.com/esss/dsdlab.

Field Test Support Processes

To demonstrate specification compliancy for complex IRCM systems, Northrop Grumman DSD needed a more effective approach than simply subjecting equipment (including aircraft and pilots) to live fire testing. A diversity of test requirements existed including ground, flight, and simulator features. This environment called for the use of rapid prototyping to enable test equipment to support aggressive schedules, while also supporting a wide range of interfaces.

Initial versions were fielded rapidly using COTS technology to support a growing number of analytical demands. Northrop Grumman DSD developed a documentation chain to trace system requirements throughout the test preparation, test conduct, test analysis, and reporting loops. Documentation provided a logical and controlled means by which parameters are allocated to specific tests; results are collected and analyzed; and final compliance is documented to the customer. Data enabled the company to use quick-look tools, combine related events, compile event timelines, and verify specification compliance. Development tests then progressed in a logical and comprehensive manner from component to integrated system levels, permitting a significant reduction in subsequent production testing.

Northrop Grumman DSD's field test support processes involve documentation and testing chains. By utilizing these chains, the company can locate problems before they cause a significant impact, and bring together four different systems simultaneously with minimal downtime due to unexpected integration problems. In addition, the development path paved the way for the production path in regard to system testing.

In-Circuit Test

Northrop Grumman DSD's development process for In-Circuit Tests (ICTs) has evolved to provide improved test performance while reducing manual labor requirements. As expected, testing has migrated from the use of product-specific dedicated test equipment to automated and semi-automated capabilities. Additionally, the process utilizes compiled libraries of automated test routines. The sharing of these test routines between functional and ICT equipment has proven to further enhance savings in both schedule and labor. Faults normally found in final tests can be identified before labor is added to install the CCA into the final assembly.

The company's current practices are derived from component specifications including specified pin assignments (e.g., power, input, output, bi-directional). Software automatically makes pin assignments for non-standard parts in a rapid and efficient manner. Peripheral benefits have included improvements in fixture development time, data entry errors, and required fixture modifications. Clearly, the automation of repetitive tasks has been the principal contributor to labor reduction. The specific recognition of duplication between functional and in-circuit testing appreciably aided this feature. Previously, the conduct of ICT development varied from minutes to hours as a function of circuit complexity. Currently, such tests can confidently be planned and conducted within minutes, despite a significant increase in the average circuit complexity (e.g., total components, interconnects). Additionally, a proactive approach is in process to significantly reduce current ICT development time.

Northrop Grumman DSD's move from stand-alone functional test equipment to ICTs contributed to better test coverage and a decrease in test development costs. Full implementation of this provision is expected to improve development costs, identify defects earlier, aid identification of field return faults, and improve fault isolation capabilities.

Material Evaluation Laboratory

Northrop Grumman DSD identified a need for an on-site high technology laboratory which could handle diagnostic failure analysis, material evaluation, and process/design analysis support. As a result, significant investment was made to establish the Material Evaluation Laboratory (MEL). MEL features an outstanding variety of special testing, diagnostics, and analytical capabilities required for testing and verifying numerous types of materials and components.

An on-site laboratory provides many benefits including timely analysis results, accessibility of expertise, and reduction in outsourcing expenses. However, reliability testing and analysis also demand a wide range of expertise and test equipment. Northrop Grumman DSD's staff of chemists, physicists, metallurgists, electrical engineers, and materials scientists provide this expertise, while MEL houses advanced test equipment including a scanning electron microscope with energy dispersion x-ray; Fourier transform infrared spectrometer; thermal analysis system; atomic absorption spectrophotometer; real-time five-axis x-ray; scanning acoustic microscope; ultraviolet spectrophotometer; tensile tester; and Rockwell hardness tester.

MEL's diversified and proven experience is a valuable tool in problem identification, analysis and responsive formulation of solutions, and specific customer challenges. The laboratory's unique capabilities and expertise have led to direct improvement in the producibility and reliability of Northrop Grumman DSD's products.

Universal Power Supply Tester

In the past, Northrop Grumman DSD designed and manufactured dedicated fixtures for use in testing each subassembly that made up a power supply unit. Each one of these dedicated fixtures consisted of several thousand dollars worth of material; took many hours to design and build; required unique test procedure documentation; and had limited testing capability. Most included some kind of power load and numerous power supplies to stimulate the unit under test (UUT). In 1995, Northrop Grumman DSD acquired an Intepro Universal Power Supply Tester which contains the loads and power supplies needed to stimulate the UUT.

The Intepro system uses an Interface Test Adapter (developed by Northrop Grumman DSD) which is simple and reliable, and allows the UUT to interface with the versatile Universal Power Supply Tester. The software employed in the testing system uses the command structure of the Powerstar integrated test environment adapted by Northrop Grumman DSD to the UUT acceptance testing requirements. The process introduced requires very little operator intervention and training, and fits within the company's overall SPC strategy.

Since implementing the Universal Power Supply Tester into its methodology, Northrop Grumman DSD has reduced its cost of test development and its touch labor to perform tests. Individual test procedures for each subassembly is no longer required. In addition, the universal nature of the Intepro system allows Northrop Grumman DSD to use identical test program codes with its customers who already own an Intepro.

Vertically Integrated Test Equipment

Traditional test approaches have included multiple configurations of test equipment which provided test capabilities across the product life cycle. The result of this low degree of test product commonality increased prime equipment support costs as well as acquisition and maintenance support of the test products. Northrop Grumman DSD developed an alternative approach for test support by merging three separate test equipment developments.

The Vertically Integrated Test Equipment combines (1) the common tester for the factory and depot support of the AN/ALQ-135, (2) the general purpose, EO test asset product, and (3) the integrated family of test equipment, general purpose, automated test equipment product line. These three test equipment developments have successfully driven the company's factory, depot, and intermediate level test functions toward a common technology base. The next goal is to inset the common test resources into the prime equipment development cycle.

The Vertically Integrated Test Equipment optimizes Northrop Grumman DSD's value-added in the test product area. Among these include maximizing the use of commercial open system architecture elements; targeting high-profile technical niches which require considerable investment but have long-term marketability; and providing system integration and standardization to preserve test program investment.

Production

Circuit Card Assembly: Conformal Coating

Previously, Northrop Grumman DSD used a manual spray method for applying conformal coating to CCAs. Per MIL-I-46058, this process was performed in a ventilated booth using an acrylic coating thinned with methylethyl ketone and toluene, both hazardous substances. When required, the conformal coating was removed by using Freon TMS, an ODC. Additionally, the boards being coated were manually masked and demasked to keep coating out of specified areas of a given CCA. In 1996, Northrop Grumman DSD acquired a Nordson Select Coat System to automate its conformal coating process and eliminate environmental hazards.

The Nordson Select Coat System uses a robotic five-axis spray head to selectively apply conformal coating. This microprocessor-controlled system also utilizes a low pressure, non-atomized spray to flow coat the CCAs. Other process improvements included switching to a conformal coating material with lower levels of volatile organic compounds (VOCs); performing the process in a continuously

ventilated work cell; and eliminating Freon TMS by changing to a semi-aqueous cleaner.

These changes to Northrop Grumman DSD's conformal coating process has resulted in a 50% reduction in touch labor by dramatically reducing the assembly masking and demasking steps. Furthermore, the company eliminated the use of hazardous materials, substantially reduced VOC and ODC emissions, and improved coating repeatability.

Electro-Optical Flexible Assembly Processes

Northrop Grumman DSD is in the process of implementing a flexible manufacturing environment for the development of EO assemblies. The company's present procedure involves the use of segregated workspaces as determined by individual programs and/or processes. This approach requires the development of expensive single-use alignment stations and excessive tooling, space, and test costs for new programs. Moreover, inflated cycle times are also required due to the frequent movement of hardware between locations. The company is developing a flexible manufacturing approach which will alleviate the inefficiencies associated with the current assembly floor layout (Figure 3-1).

The flexible manufacturing environment will utilize a cellular approach and the development of several flexible capabilities including tooling, alignment systems, and test systems. These capabilities will be flexible in the sense that they can be used for multiple programs with minimal setup time when switching between programs. The supporting

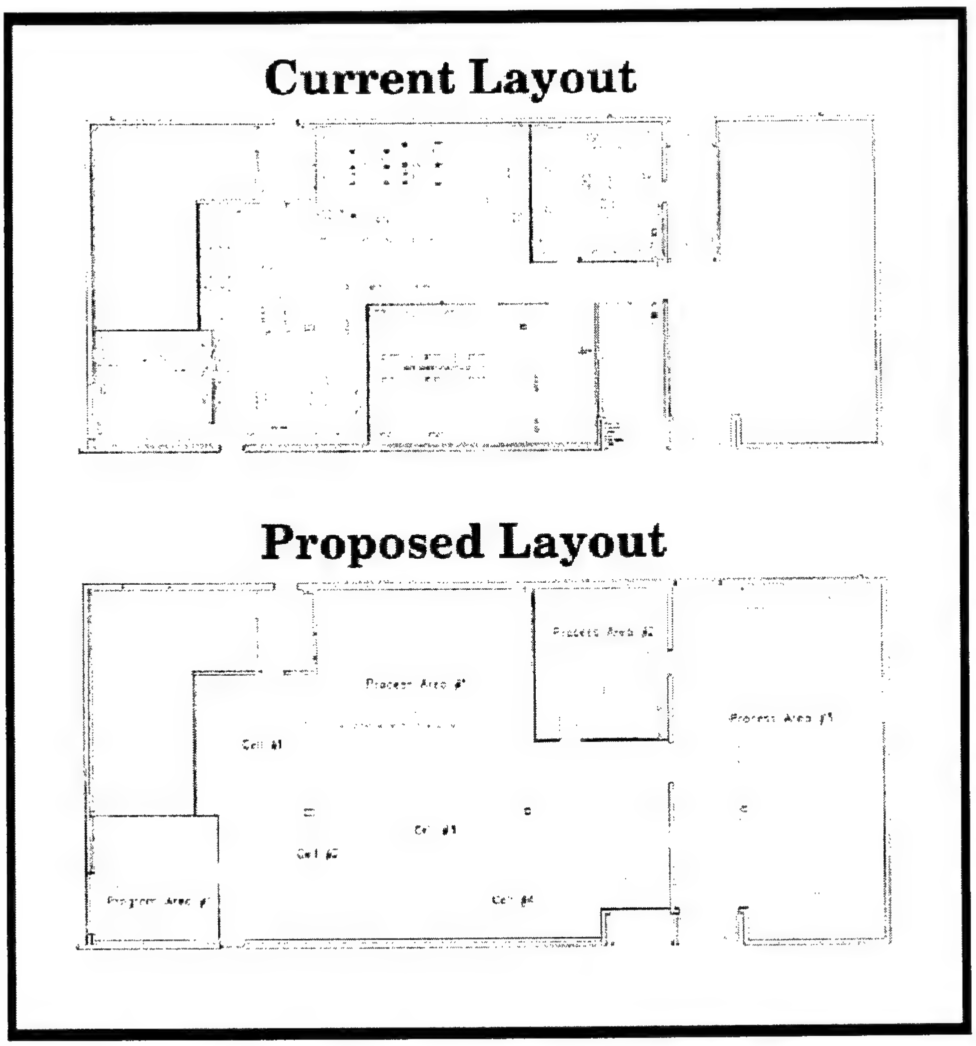


Figure 3-1. Current versus Proposed Layout

alignment and test systems will be located close to the assembly area to create work cells, minimize hardware movement, and reduce cycle times. Northrop Grumman DSD has identified projects to simplify the tooling required for EO assembly and ensure that future designs will be developed within the capabilities of the manufacturing, alignment, and test systems.

The company expects the flexible manufacturing environment to significantly reduce capital and tooling of future programs by standardizing the work cells. Other anticipated benefits include a reduction in the development of work instructions, decreased cycle times, and increased throughput without additional facility expansion.

Encapsulation and Impregnation

Northrop Grumman DSD builds a number of assemblies that require encapsulation or impregnation. An encapsulated or impregnated assembly is typically an electrical device (e.g., high voltage power supplies, ignitors, modulators, transformers) requiring a protective coating of material to fill all spaces between components and around the exterior surfaces. In most applications, the encapsulant material is silicone, epoxy, or urethane. In the past, process yields were relatively low (50% to 60%) especially on start-up items, and required 100% inspection by QA. Voids in the encapsulant were common. Process traceability was very difficult because it relied too much on manually generated logs and operator memory. Northrop Grumman DSD has implemented a number of improvements for encapsulation and impregnation.

The current practice institutes these changes:

- SPC is used in critical areas to ensure that the manufactured product maintains certain build criteria from lot to lot. These parameters include cleanliness testing, viscosity measurements, adhesion testing, and hardness readings.
- Grit blasting was replaced by plasma etching to prepare the part surfaces before encapsulation, resulting in cleaner parts with better adhesion.
- Design for Manufacturability is instituted by Operations on all new product types. This approach ensures that the development, design, and manufacturability of new products enable the company to continue producing quality encapsulated and impregnated assemblies efficiently.
- Northrop Grumman DSD has empowered its operators by training them to perform 97% of the in-process inspections.
- The Encapsulating Team developed a handbook, *Encapsulation for Dummies*, for operators and design groups as a source of information on these processes and failure analysis.

Since implementing these changes, Northrop Grumman DSD has greatly increased its process yields on encapsulated and impregnated items; eliminated voids; and reduced analysis costs. Empowerment has also increased operator awareness, resulting in higher quality products and quicker isolation of problems.

J-STD-001 Workmanship Training

Previously, Northrop Grumman DSD spent 10,560 hours per year training and re-certifying 191 personnel to fulfill the requirements of MIL-STD-2000. Re-certification typically ran three days to complete the 24 hours of training. Operators and inspectors were required to take different classes and obtain separate certifications. In April 1997, a block contract change for the ALQ-135 program provided the company with an opportunity to revise its training practices and transition to the J-STD-001 Workmanship Training.

Following this event, Northrop Grumman DSD developed a customized, internal workmanship standard, 499-000008, based on J-STD-001 and IPC-A-610. An eight-hour re-certification class was also created to familiarize personnel with the new standard. Operators and inspectors take the same class which eliminates separate certifications. The class involves a 35-mm slide test to demonstrate acceptance criteria, a written test to demonstrate specification knowledge, and a sample CCA build to demonstrate proficiency. Re-certification periods were extended from 12 to 18 months based on an industry survey. Standard practices and policies include SP 16-18.00 Formal Classroom Training, On-The-Job Training, and Training Records; EB12-04.10 Training and Certification; I.P.2.4.0.13 Product Operations Training Center Inspection & Soldering Certification Policy; I.P.2.4.0.51 Product Operations Training Center; and I.P.2.4.0.52 Electrostatic Discharge Training Certification Program.

Northrop Grumman DSD also maintains a state-of-the-art Product Operations Training Center to train and certify its production personnel. Instructors are certified for J-STD-001 and IPC-A-610 training through the Electronics Manufacturing Production Facility. The training center contains ten workstations, each equipped with a Metcal soldering station and a microscope. Classroom instruction includes J-STD-001 and IPC-A-610 specification requirements review, hands-on soldering and inspection, and both written and visual tests using 35-mm slides of soldering/assembly defects. The company maintains a database with the employee's name, number, training class completed, certification date, and

test score. A sample of each employee's training CCA or work is also kept on record. Personnel are re-certified at least every 18 months, or earlier if random Process/Product Assessment audits indicate a need for additional training.

Since implementing the J-STD-001 Workmanship Training, Northrop Grumman DSD decreased its training from 10,567 hours for 191 employees in 1997 to 2,599 hours for 178 employees in 1999. Other benefits include dual certification for operators and inspectors, a streamlined training program, and a more flexible workforce.

Magnetics

Magnetics are transformer-type devices that have the primary function of regulating voltages in an electronic device. Northrop Grumman DSD has over three decades of experience in designing and manufacturing magnetic components. Approximately 372 magnetic types have been produced on 21 programs, varying from a one-gram air coil to a 27-pound step-up transformer. All magnetics are built to meet the requirements of MIL-T-27. Past practices at Northrop Grumman DSD dictated that all magnetics be 100% tested by QA. Surface preparation, if required, was performed on a one-by-one basis using labor intensive and inconsistent grit blasting. The materials used were not robust, and therefore unrepairable if defective. The use of carriers to facilitate the ease of assembly was also non-existent. To resolve these issues, Northrop Grumman DSD underwent a fundamental paradigm shift in its practices.

Northrop Grumman DSD provides the necessary training and tools to its production operators, empowering them to perform in-process inspections on 98% of all magnetic product types. QA inspects the remaining 2%. Where possible, carriers have been added to the product designs to assist in assembly. Other improvements include replacing grit blasting with plasma etching of components to improve adhesion; using robust materials to allow repair/rework of some defective products; and performing surface preparation on a lot basis. Process controls established include Design of Experiment, Design for Manufacturability, and SPC for critical design parameters (e.g., wire tensile strength, cleanliness). Design for Manufacturability is instituted by Operations on all new product types, enabling Northrop Grumman DSD to continue producing quality magnetic components efficiently.

As a result of these improvements, Northrop Grumman DSD instituted a findings feedback loop via e-mail to Design Engineering. These findings are used to refine future designs and avoid past problems. With design directions evolving toward smaller packaging, increased power, less environmental sensitivity, and simpler assembly at 98%+ yields, Northrop Grumman DSD's initiatives position the company to continuously improve the quality, reliability, and cost of its magnetic components.

Material Control and Kitting

In the past, Northrop Grumman DSD's material control and handling practices were antiquated, inefficient, and disorganized. Receiving Operations attempted to maintain thousands of components in 600 sections of ten-foot high racks. Three-by-five index cards were used for part traceability, shelf-life information, and first-in-first-out (FIFO) processing. Dock-to-stock cycle times were unknown, and electrostatic discharge (ESD) protection was non-existent. Order-picking Activities faced a never-ending backlog of work. A cycle time of 65 working days was needed to issue pick orders. Material Auditing recounted and performed 100% verification of each line item of material picked, as well as wrote out the pick-and-audit sheet for each shop order. The result was thousands of hours of overtime, excessive costs, and a lack of goals. In 1989, Northrop Grumman DSD implemented the Storage Tracking Automated Retrieval System (STARS) as part of the company's total quality effort.

STARS provides on-line, real-time transaction processing. Parts are efficiently stored and retrieved in horizontal and vertical carousels, utilizing barcode technology and automated trackbots. The system also features FIFO logic, lot control, serialization, visibility of shelf life, product by program, and off-site stock locations. STARS is integrated with the IMCS Shop Floor Control System. All material is verified against purchase orders and dispositioned by on-line transactions. Barcoded material travelers are used and lot number association is issued by Receiving.

Shop order issue-to-production is also driven by IMCS via production control or auto release. The mainframe provides information to Kitting, which describes the workcenter bin list for each kit based on the automated work instructions for each assembly number. Kits are consolidated, audited for accuracy and completeness, and then issued to each requiring workcenter separately as build-ready kits. In this manner, material handling is minimized, and parts are issued when and where they are needed. The audit process ensures that parts conform to specifications (e.g., proper packaging, orientation, correct revision, alternate/substitute status). If discrepancies in the work instructions are discovered, then Process Systems Engineering is notified. Metrics are maintained by measuring kitting efficiency, accuracy, and cycle time. The primary metrics flow into the EPI program, providing objective performance measures for the department and motivating team improvement. Since metrics tracking began in 1990, the process time, accuracy, and cycle time of kitting have steadily improved and now exceed departmental objectives.

Since implementing STARS, Northrop Grumman DSD has significantly improved its Material Control and Kitting practices to remain competitive and profitable. Dock-to-stock cycle times are now measured in hours and days. Lot number association provides complete traceability of components throughout the system. Operators are ESD certified, and appropriate ESD protections are in place. Shelf life is monitored with automatic updates regarding impending obsolescence, and FIFO priorities are automatically performed. The company facilitates continuous improvements through active solicitation of its customers.

Statistical Process Control

Northrop Grumman DSD has applied SPC to the evaluation and analysis of test result data. The measurement of key product characteristics is automated, and the data is treated as SPC data points. The data points are compared to historical control limits as well as specification limits to determine if any are considered out of control. Out-of-control data points are automatically identified and then addressed by Operations Engineering. Control limit updates are made based on changes in the process variability and when a significant amount of data has been collected. The SPC system provides a method for collecting real-time data and enables real-time assessment of product quality.

Past process control and variability reduction methods were managed using labor-intensive manual data collection and analysis methods. Northrop Grumman DSD's introduction of a fully integrated SPC system into the main production floor was completed in 1994, and is currently being expanded to other shop operations areas. The SPC system can display control charts on-line with detailed drill-down information by assembly, serial, material, or lot number. These charts are displayed at the end of each batch. Users can add/edit comments to the individual control chart points to identify information relevant to the process. The system also can be set up to prevent further processing until corrective action is addressed. The chart advisor is an on-line data analysis graphical and report interface for performing data analysis calculations and displaying output (e.g., Pareto, histograms) from the SPC system.

Since implementing the SPC system, Northrop Grumman DSD has realized several benefits. Among these are reduced rework and repair time; facilitation of systematic process improvement initiatives; and decreased cycle time and costs attributed to timely identification of out-of-control processes.

Logistics

Engineering Staffing Projections

Project staffing projections at Northrop Grumman DSD were usually done at the beginning of a program and at ad hoc periods during the program. Follow-on needs were accomplished with minimal relation to engineering skill mix required, and the concept of core members was used to a limited extent in project group assignments. The company soon recognized the need to efficiently and effectively allocate engineering personnel through its growing program environment. The company needed to support product lines with teams of core individuals possessing product knowledge and heritage, as well as optimize the availability of engineers' critical skills and move them quickly across projects.

The Engineering Project Manager (EPM) is tasked in achieving the project's technical goals, Cost Performance Index, and Schedule Performance Index. The EPM must also control the tasking of personnel assigned to the team. The desire is to have a team of technical personnel working with Engineering Project Management. The core team stays with the project on a long-term basis, and the staff is efficiently allocated and reassigned as needed.

Stable staffing of key engineers as well as flexible, part-time engineering personnel are desirable. In early 1999, Northrop Grumman DSD developed a method for identifying and forecasting specific staff requirements for functional managers. The method involves the publication of a monthly staffing projection spreadsheet. The spreadsheet lists employees' names, their skill type, and a designation as either core or shared-across projects. The scheduling forecast covers a six- to 12-month range for various categories (e.g., product line, program, tasking, monthly man hour tasking), and enables functional managers to quickly identify staff shortfall or excess for reallocation.

Since implementing these Engineering Staffing Projection practices, Northrop Grumman DSD has realized several benefits. Among them are manageable staff loads, allocation of team members without department transfers, and lower engineering labor.

Product Operations Depot

The Product Operations Depot is a service organization within Northrop Grumman DSD that repairs and retrofits line replaceable units (e.g., control oscillators, RF amplifiers) and shop replaceable units (e.g., modulators, power supplies) for various customers. The Depot is comprised of four major functions: Administration, Production Control, Test and Repair, and Material Control. In the past, the

Depot had no access to TRNs which, among other things, provide failure thresholds and integrated corrective actions (both process and supplier). Consequently, the ALQ-135 program experienced a high rate of correlation failures resulting in decreased system reliability, poor customer satisfaction, and high product quality deficiency report rates. To resolve these issues, the Depot implemented BVM practices where appropriate to specific customer requirements for depot-level support.

The Depot is also working to reduce and streamline the contract data requirements list (CDRL) deliveries for its customers by providing contract data in an electronic format. For example, the ALQ-135 Depot Support Contract calls for maintenance data collection records (AFTO 349 Form) to be submitted for each depot-level repair. A project is underway to collect the required maintenance data (e.g., TRNs, daily assignment ticket system labor, depot material, logistics) electronically from the operations and depot data systems to meet CDRL requirements. This effort will greatly reduce the time to produce CDRL data and provide customers with accurate and timely information. The Depot is producing approximately 5,000 to 6,000 TRNs each year. The data is collected by Sustaining Engineering and Depot personnel to assist in trend and failure analyses, the troubleshooting and repair of customer systems, and the correlation of production and field failures.

In July 1995, the Depot was designated as Zone 10 for the EPI program. Its mission is to establish SPC metrics to measure and evaluate Depot performance; use performance measures to reduce costs and product turnaround times while improving product quality and customer satisfaction; and provide guidance, leadership, and communication to all zone members for the implementation of EPI.

Zone 10 has consistently shown marked improvements and won quarterly and annual awards for its efforts. As a result, the Product Operations Depot has reduced its rates of return, increased customer satisfaction, and provided high system availability. All new program bids now include the use cost of supplier-developed test systems to reduce correlation issues. These efforts assist Northrop Grumman DSD in producing quality products for its customers.

Shelf Life Management System

In 1980, Northrop Grumman DSD developed the Shelf Life Management System which sets the shelf life of materials. The system is flexible so it can adapt to transition programs, and provides users with material classification, shelf life definitions, labeling procedures, procedures for change, and storage/handling requirements.

The system also utilizes an on-line shelf life reference list. This database is accessible through the local network and used mostly by receiving inspectors, stock room personnel, engineers, and operators. The database also provides part number cross-references for almost 1,800 items as well as descriptions, shelf life, shelf life categories, storage classes, and percent shelf life extensions. Requests for extending the shelf life of a material are submitted to the Material Evaluation Laboratory. Tests determine if the performance of the material still meets specification. Rejected items are scrapped and the requester is notified. Materials that pass typically receive a shelf life extension of 25%.

Since implementing the Shelf Life Management System, Northrop Grumman DSD has decreased material costs by re-certifying items rather than scrapping them; reduced hazardous waste disposal cost and liability; achieved material requirements feedback; and established a part number cross-reference. The company also attains a better understanding of material performance through the extensive history of test and shelf life extensions.

Technology Planning

Healthy Research & Development investments are vital to the stability of advanced systems programs. Previously at Northrop Grumman DSD, this process involved proposing projects and allocating funds over a period of several months. IRAD budgets were then approved and allocated for the projects. However, this process did not yield satisfactory levels for Contract Research and Development (CRAD). A goal was set for CRAD dollars to be committed at three times the IRAD amount. Due to the expedient process of approval and allocation, customer needs were not satisfactorily being met with the proposed projects and CRAD investments were less than projected. In 1996, Northrop Grumman DSD introduced Technology Planning to improve the methods by which approval and allocation of IRADs occurred.

Technology Planning is a disciplined process for the planning and execution of internally funded technology development. The process is closely tied to the development of the Long Range Strategic Plan and the Annual Operating Plan. Technology Planning includes the definition of specific needs and requirements for specific product lines; the ranking of those requirements; and their translation into specific technology development objectives. In addition, the process requires the close coupling of customer-funded Research & Development to ensure synergy between customer needs and technology development. A key change is that the projected funding for IRADs is approved in May, prior to the project proposals being made. Plenty of time is then allowed for the Principal Investigators (PIs) to prepare summary project proposals by August for

next year. Plans are reviewed/revised for the Operating Plan in October. Executive reviews for market segment funding and PI detailed plans are completed concurrently in December. Projects are then reviewed quarterly to encourage program office participation. Items reviewed may include objectives, open issues, determined risks, and restatements of the tasks they are doing.

Technology Planning enables Northrop Grumman DSD to focus its R&D efforts on those projects in which the customer wants to invest. These projects are also supported by an increase in CRAD investments by approximately a factor of three. Technology Planning also provides the company with out-year business stability, current year project stability, less planning overhead, and an organized structure to take better advantage of opportunities.

Management

Electronic Command Media Web

In 1993, Northrop Grumman DSD first implemented an electronic documentation system to establish controlled versions of documents and reduce the cost of maintaining a paper-based system. Although initially limited to management policies, procedures, organization charts, and revisions, this first electronic system evolved into an Intranet-based documentation system known as the Command Media Web. This centralized controlled system provides site-wide access to the most current versions of corporate, sector, and departmental command media; forms; and other general interest information.

The Command Media Web is continuously evolving, and the reduction of redundant documentation is a key objective. Operations is currently reviewing and condensing all of the documentation into two categories: Auditable Operations Process Documents and On-The-Job-Training Documents. The use of process mapping techniques on the Stores and Staging Consolidation Pilot Project resulted in a 71% total reduction in documentation. This consolidation effort is planned for implementation throughout the organization to minimize detail, process time, and audit findings, and improve process understanding.

The Command Media Web recently began featuring an e-learning program (formerly computer-based training), which offers hundreds of on-line software training courses for employees. A wide range of topics is available including basic computer skills, programming languages, networking, and business applications. Employees register using an on-line form, pending manager approval. An annual license fee of $215 is charged to the employee's organizational budget for participation in the e-learning program.

The Command Media Web is accessible to all Northrop Grumman DSD employees and contractors through unclassified network computers. The Intranet site is currently receiving more than 8,000 hits per day, which is up nearly one-third from last year's numbers. In addition, the number of visitors and the amount of time spent on the website has increased by about 30% over last year's averages. Information on the Command Media Web is updated daily to ensure the latest version of documents is available, reduce the chance of using obsolete documentation, and eliminate the costs associated with maintaining hard-copy manuals. Hyperlinks and search capabilities enable users to quickly locate data, thereby minimizing redundancies and conflicts between documents. The implementation of the Command Media Web has resulted in the development and publication of higher quality documents for use throughout Northrop Grumman DSD.

Employee Development and Recognition

Northrop Grumman DSD has instituted various Employee Development and Recognition programs. Initial efforts began with educational classes at the local community college and expanded into graduate degree work. Additionally, the company established formal programs to recognize and award its employees for outstanding performance on the job.

Northrop Grumman DSD maintains strong relationships with local educational institutions, and draws on their resources to assist with the further enhancement of the company's educational needs. Since 1979, the Illinois Institute of Technology's Interactive Instructional Television system has been a mainstay of Northrop Grumman DSD's technical education efforts. The coursework, delivered by line-of-sight transmission from the John Hancock Building in Chicago, has produced many Masters Degree and Doctoral recipients within the company's workforce. Northrop Grumman DSD's partnership with the William Rainey Harper Community College has spanned over 30 years. Here, employees have been involved in numerous capacities such as student, adjunct faculty, Advisory Boards, Educational Foundation Board, and Board of Trustees. The company frequently brought Harper College coursework on-site to assist employees in furthering their formal education. Another relationship is through the local high school district to foster employee enhancement of mathematics, reading, comprehension, and English as a second language.

Several programs have been implemented to recognize outstanding contributions by employees:

- The Quality Award Program provides recognition and monetary rewards to Operations personnel whose exemplary efforts result in high quality production.

- Efforts are acknowledged in various areas including customer satisfaction, exceptional effort, problem resolution, valuable suggestions, high yields, and process, system, or product improvement.
- The Timely Awards Plan provides timely recognition and remuneration of outstanding individual and team accomplishments beyond their normal performance. Nominations are made by supervisors, managers, or team leaders. The Director of Human Resources and the Employee Recognition Committee review the nominations and determine the award levels.
- The President's Leadership Award recognizes outstanding employees who demonstrate leadership qualities through their accomplishments. These employees attend a dinner in their honor and receive a plaque of commendation.

Northrop Grumman DSD's Employee Development and Recognition programs have been valuable motivators that encourage education and success. Employees achieve satisfaction and self-esteem through education, acknowledgment, and teamwork. Recent years have shown an upward surge in educational enrollment. Participation in Harper College partnerships have increased from 14% in 1998 to 35% in 2000.

Environmental and Safety Web-Based Interactive Training

Previously at Northrop Grumman DSD, the EHSM staff educated employees on environmental and safety topics by conducting group training classes. Classes involved slide presentations followed by manually administered tests to demonstrate competency of the group. In some cases, CD-ROM interactive, multimedia-based, pre-packaged programs were used to assist in the training needs. These programs were semi-customizable and contained interactive features which offered immediate feedback and ensured uniform testing. EHSM further revised these methods by developing the Environmental and Safety (E&S) Web-Based Interactive Training.

The E&S Web-Based Interactive Training is an environmental awareness training module that incorporates multimedia (e.g., voice, image, video) and interactive testing in a web-based format. Deployed over the company's Intranet, this effective compliance tool allows employees to participate in training sessions at their own time and pace. The web-based modules provide more consistency than a live instructor, and the multimedia features can imitate an instructor's stimulation, interest, and rate of information for the employee. Testing is automatically sent to the Environmental, Health, and Safety (EH&S) Department for record keeping. Northrop Grumman DSD is currently developing other web-based, environmental awareness training modules such as Safety Orientation for New Employees, HazCom Update, Lockout/Tagout, Emergency Response, and Office Ergonomics.

To minimize the impact of large sound and video files to the network and workstations, EHSM employs a streaming media format for the training modules. This format compresses the files, enabling them to be continuously streamed to the user and eliminating the need to download the file prior to starting the training session.

Web-based training is an effective tool that reduces EH&S labor to perform training, increases departmental scheduling flexibility, and provides a manageable method to track training needs and regulation compliancy. Additionally, the E&S Web-Based Interactive Training can easily be updated as regulations and processes change.

Intranet Program Review System

The Intranet Program Review System (IPRS) is an online method for reporting program status on selected projects within Northrop Grumman's Electronic Sensors & Systems Sector. The IPRS defines a standard program reporting format which is used for monthly status, business area reviews, vice presidential quarterly program reviews, and corporate program reviews. The format of the report dictates the minimum materials required for program reviews, and provides flexibility to incorporate supplemental charts when necessary.

The password-protected system is used by project managers to report program status and by senior-level managers to review status. Each monthly assessment employs uniform objective metrics to ensure that consistent data is provided. Program managers are responsible for entering data into the IPRS prior to the last day of the month. This data is entered in a pre-defined template format. The system features an e-mail interface that automatically transmits questions and concerns to the appropriate personnel. The responsible manager indicates final approval of the report by the fifth day of each month; comments can be inserted as necessary. The system's interfaces are automated and provide users with menus and hot links within the reports for ease of use.

The IPRS' strength as a management tool is its uniform nature of the grading criteria used to review and approve program status reports. This attribute ensures that objective quantitative assessments are performed for each report submitted. The IPRS formalizes the review process by standardizing the timing, content, and order of the reporting system across all sites within the Electronic Sensors & Systems Sector. As a result, all program reviews are

reported and viewed in the same manner. The IPRS has greatly reduced the need for formal briefings, but serves as a building block for developing consistent briefing packages when a formal briefing is required.

Material Acceptance: Dock to Stock

Previously, all material at Northrop Grumman DSD was 100% inspected. This approach required significant investment in inspection equipment and labor. Backlog of material awaiting inspection and high failure rates of incoming material were commonplace. In 1996, Northrop Grumman established the Material Acceptance: Dock to Stock. This inspection-free material acceptance system shifted the emphasis for product acceptance from the company to the suppliers.

The automated Material Acceptance: Dock to Stock is integrated with the company's Supplier Rating System. Dock to Stock provides prioritization of receiving inspection workload, barcoded labels, and standard quality requirements on-line to Receiving Inspection. Commercial and catalog products are no longer inspected or tested. Overhead was reduced by eliminating the inspection of suppliers/part numbers that have excellent historical performance. As of October 1999, Northrop Grumman DSD attained a rate of 75% for all of its material received and processed to stock without inspection.

Cycle time for inspections have been reduced to approximately one hour per lot by focusing on attributes that have been historically problematic or are program critical. Since implementing the Material Acceptance: Dock to Stock, Northrop Grumman DSD has increased its acceptance rate of material by 99%; decreased inspection personnel by 80%; and reduced material backlog from 2,000 lots to less than 25 lots.

Operations Programs Integrated Product Team

The Operations Programs Integrated Product Team (IPT) is responsible for providing direction and coordination for all of Northrop Grumman DSD's operational activities. The primary functional activities are Production Planning & Scheduling; Operations Project Engineering; Material Planning & Control; and Operations Business Management. The Operations Programs IPT provides the insight and support required to develop new programs and transition them to full-scale production. To accomplish this goal, the group is responsible for:

- Establishing program requirements and schedules.
- Translating requirements into a manufacturing program plan, which is in-line with Operations' goals and resources.
- Interfacing with other operations organizations to ensure implementation of the plan.
- Providing departmental business requirements planning to support Operations' objectives for proposal development and negotiations; direct budgets; and cost-performance analysis and reporting.
- Acting as the primary interface between Operations and all functional departments within Northrop Grumman DSD for program definition and scope; performance to schedule and budget; and resolution of technical and/or engineering issues.

In the past, Northrop Grumman DSD operated as a matrix organization. This approach provided professional stability of functional experts and minimal duplication of common parts, practices, and processes. However, additional costs resulted from increased coordination between functions, lack of ownership at the program level, and limited knowledge of the program/product line. Today, Northrop Grumman DSD's product organization structure has resulted in a 38% reduction in support personnel; extensive knowledge of the product line; and strong team spirit/ownership. Some duplication still exists on common low value material. The changeover to a product organization structure was largely driven by an increase in program/product lines (from two to 20) and by budget constraints which forced the company to reduce the number of direct/indirect support personnel. In addition, the company's 1994 merger with Grumman Aerospace Corporation increased its geographical sites from one to four; part numbers from 5,000 to 100,000; and subcontractor/vendor base from 2,000 to 4,200.

The implementation of IMCS was critical in providing the fundamental framework to leverage the near-seamless database information flow within the Northrop Grumman DSD infrastructure. The initiative to establish a Product Project Authorization Code allows this facility to collect costs under a single account number, and then allocate them based on delivery and master sales plans. The results are contract schedule flexibility; reduced procurements and shop orders; simplified time card and cost reporting processes; and better product cost visibility. The IMCS subsystem modules (e.g., Auto Requisition/AutoBuy; Auto Transfer) were also instrumental in establishing the Operations Programs IPT. The IMCS, combined with off-line models, can generate automated reports for manufacturing metrics, material metrics, earned value process, equivalent units, and budget performance.

By implementing the Operations Programs IPT, Northrop Grumman DSD reduced its support labor by about $2 to $3 million per year for direct/indirect personnel. The changeover from traditional roles within a matrix organization also resulted in about $3 million per year in cost avoidance.

Product Data Management

In 1996, Northrop Grumman DSD initially implemented PDM as part of the MFEWCM initiative. This U.S. Air Force MANTECH, cost-sharing initiative is being developed using Metaphase II, a COTS product data management system. In 1999, a pilot application was completed and proven successful in a contained environment. A management decision was then made to transition MFEWCM PDM to the entire enterprise. A pilot project was selected for this phase, and training was provided to more than 130 new users. The company focused on making the PDM integrated system more user-friendly through web-based capabilities so it would be adaptable to an enterprise-wide environment.

Several systems enhancements have been completed including customizing and upgrading Metaphase II to a web-browser version; Intranet access to PDM; site-wide drawing and document viewing capability; user log of actions and accept/reject capability; and on-line viewing and mark-up of 3-D drawings. The company has also trained personnel and established concurrent engineering procedures. These efforts helped to establish PDM as the routine method for conducting business in current and future programs. PDM also features a single repository for all product data (e.g., manufacturing process documents, tooling drawings) to support the environment at Northrop Grumman DSD.

Other enhancement initiatives are currently in process and are expected to be completed in 2000. Once completed, these initiatives will make PDM an on-line standard practice, providing real-time data for use by Northrop Grumman DSD.

Software License Verification Process

Currently at Northrop Grumman DSD, software license records are maintained by individual organizations. This approach is time consuming, potentially inaccurate, uses manual auditing to verify license compliance, and lacks consistent traceability to primary company records. To reduce the potential for liability under the current system, Northrop Grumman DSD is developing a Software License Verification process which is expected to be implemented in July 2000.

The Software License Verification process will use a centralized automated system to provide an effective method for controlling licensed software. Unique validation criteria (e.g., purchase order, software/hardware keys, certificate) will be used per product family. A database will maintain the verified software licenses, and be linked to the specific assets on which they are installed. License information will be entered into the database. The System Management Server will audit systems and provide a snapshot of software installed on each computer. The data collected will be compared to the software license database for discrepancies. Exception reports will then be generated and sent to the using organization's management for resolution.

The Software License Verification process should reduce the risk of license violation and liability. The central database will also provide license traceability to primary company records. Northrop Grumman DSD anticipates a savings of $62,000 per year by eliminating manual audits of computers to verify license compliance.

Strategic Planning

Previously, the Operations Department at Northrop Grumman DSD did not have a formal planning process. Long-term planning was ad hoc. Operations tended to focus on satisfying near-term issues, and its planning was more tactical than strategic. Ineffective methods were used to communicate plans and objectives. Until 1995, Northrop Grumman DSD primarily produced one major product. By 1999, the company had 12 programs in production and the Operations Department had evolved into being a manufacturer of highly complex, high mix, low volume systems and subsystems. Estimations indicated that 24 programs would be transitioned into production by 2005. Operations realized it needed to invest in a forward-looking planning document, since the quantity of programs in production would double during the next five years. As a result, Operations developed and implemented a Strategic Plan.

The Strategic Plan is used to document Operations' manufacturing vision from 2000 to 2005, as well as the strategy and specific plans needed to implement that vision during the next two years. Northrop Grumman DSD uses this plan as a focus tool in guiding the allocation of resources and in establishing the performance objectives for employees. Operations uses the plan as a key communication tool for department employees, division executive management, business area management, and functional management. The plan is accessible via hard copy, Operations' Intranet website, and at all-hands meetings.

In 1999, Operations released its first strategic plan which will be updated annually. This plan establishes a series of internal benchmarks by which Operations will evaluate its progress and achievements every year. To frame the plan, Operations established five core goals: satisfy customers; remain employer of choice; build affordable products; maintain quick reaction/time to market; and assure next-generation capability. In addition, five focus areas were adopted to achieve these goals and organize the plan. These

focus areas are leadership and people; process and tools; performance; facilities and capital infrastructure; and technology.

By developing a Strategic Plan, Operations established a stated vision and mission along with issues, challenges, strategies, and goals which are defined, elaborated, and documented in one location. The Strategic Plan is a valuable tool that can evolve to meet the broadening internal and external environments of the Operations Department.

Supplier Rating System

In 1993, Northrop Grumman DSD created a Supplier Management Program designed to minimize incoming inspection, reduce the company's supplier base, and develop a supplier recognition program to reward superior performance. The previous system required personnel to manually calculate supplier ratings and reports. No integration existed with the company's inspection, quality, or procurement systems. As a result of organizational mergers in 1996, Northrop Grumman DSD's supplier base had grown to approximately 4,000.

Key to the Supplier Management Program is the Integrated Supplier Rating System (ISRS), which measures supplier performance for delivery and quality. ISRS was designed to allow for continuous improvement by utilizing tables that permit thresholds to be raised as performance improves. A unique aspect of ISRS is the integration of data into the company's procurement and quality systems. Features of ISRS include:

- Automated lockout for unapproved or disapproved suppliers, as well as suppliers with poor ISRS product ratings.
- Electronic approvals by management to override automated lockout for suppliers with poor ISRS product ratings.
- ISRS report cards for suppliers.
- Automatic utilization of ISRS quality performance data to determine the acceptance testing necessary for each product received.

Since implementing ISRS, Northrop Grumman DSD has reduced its supplier base to less than 1,200. In addition, the supplier rating system provides QA with the flexibility to perform supplier analyses at varying levels (e.g., part, commodity, supplier, site) for the current month as well as three-, six-, or 12-month periods.

Appendix A
Table of Acronyms

Acronym	Definition
ACOTS	Automated Customer Order Tracking System
AEI	Automated Equipment Interface
AEOP	Annual Environmental Operating Plan
ASIC	Application Specific Integrated Circuit
BIT	Built-In-Test
BVM	Best Value Manufacturing
CAD	Computer Aided Design
CAR	Corrective Action Result
CCA	Circuit Card Assembly
CDRL	Contract Data Requirements List
CER	Cost Estimating Relationship
COTS	Commercial Off The Shelf
CRAD	Contract Research and Development
DCMA	Defense Contracts Management Agency
DDC	Direct Digital Control
DKB	Diagnostic Knowledge Base
DOD	Department of Defense
DSD	Defensive Systems Division
E&S	Environmental and Safety
EDI	Electronic Data Interchange
EH&S	Environmental, Health, and Safety
EHSM	Environmental, Health, and Safety Management
EO	Electro-Optical
EPI	Excellent Performance Indicators
EPM	Engineering Project Manager
ESD	Electrostatic Discharge
ETA	Environmental Technical Assistance
FIFO	First-In-First-Out
FSM	Facilities Service Manual
HMM	Hazardous Materials Manager
HMMP	Hazardous Materials Management Program
HVAC	Heating, Ventilation, and Air Conditioning
IC	Integrated Circuit
ICT	In-Circuit Test
IMCS	Integrated Management Control System
IPRS	Intranet Program Review System
IPT	Integrated Product Team
IR	Infrared
IRAD	Internal Research and Development
IRCM	Infrared Countermeasures
ISRS	Integrated Supplier Rating System

Acronym	Definition
JIT	Just-In-Time
LAI	Lean Aerospace Initiative
MBOM	Manufacturing Bill of Material
MEL	Material Evaluation Laboratory
MFEWCM	Modular Factory for Electronic Warfare Component Manufacturing
MMAS	Material Management Accounting System
MMIC	Monolithic Microwave Integrated Circuit
MPM	Microwave Power Module
MRP	Material Requirements Planning
MRP II	Manufacturing Resource Planning
MSDS	Material Safety Data Sheets
NMR	Nonconforming Material Report
ODC	Ozone Depleting Chemical
P/M	Preventive Maintenance
P2	Pollution Prevention
P.A.R.T.S	Product Assurance Replacement and Trending System
PDM	Product Data Management
PI	Principal Investigator
PPSL	Preferred Parts Selection List
PROCAS	Process Oriented Contract Administration Services
PWB	Printed Wiring Board
QA	Quality Assurance
RF	Radio Frequency
SARA	Superfund Amendments and Reauthorization Act
SEEAC	Security Education and Ethics Awareness Committee
SPC	Statistical Process Control
SPI	Single Process Initiative
SSIP	Security Safety Inspection Program
STARS	Storage Tracking Automated Retrieval System
TRN	Test Result Notice
TWT	Traveling Wave Tube
UUT	Unit Under Test
V&V	Verification and Validation
VOC	Volatile Organic Compound

Appendix B
BMP Survey Team

Team Member	Activity	Function
Larry Halbig (317) 891-9901	**BMP Field Office** Indianapolis, IN	**Team Chairman**
Cheri Spencer (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**

Design & Test Team

Bob Harper (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Team Leader**
Constantin Rauta (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Luke Kluender (812) 854-6462	**Naval Surface Warfare Center** Crane, IN	

Production & Facilities Team

Richard Goodwin (909) 273-5472	**Naval Warfare Assessment Station** Corona, CA	**Team Leader**
Michael Hunt (317) 587-4427	**Thomson Consumer Electronics** Indianapolis, IN	
Robert Campbell (814) 865-8959	**Applied Research Laboratory** The Pennsylvania State University State College, PA	

Management Systems Team

Candance Lasco (317) 587-3323	**Thomson Consumer Electronics** Indianapolis, IN	**Team Leader**
LTC Ming Chin (703) 805-3768	**Defense Systems Management College** Fort Belvoir, VA	
Jack Tamargo	**BMP Satellite Center**	

(707) 642-4267	Vallejo, CA	

Management & Logistics Team

Sophy Wong (909) 273-4994	**Naval Warfare Assessment Station** Corona, CA	**Team Leader**
Renee Strain (301) 403-8100	**BMP Center of Excellence** College Park, MD	
Thomas Clark (815) 654-5515	**BMP Satellite Center** Rockford, IL	

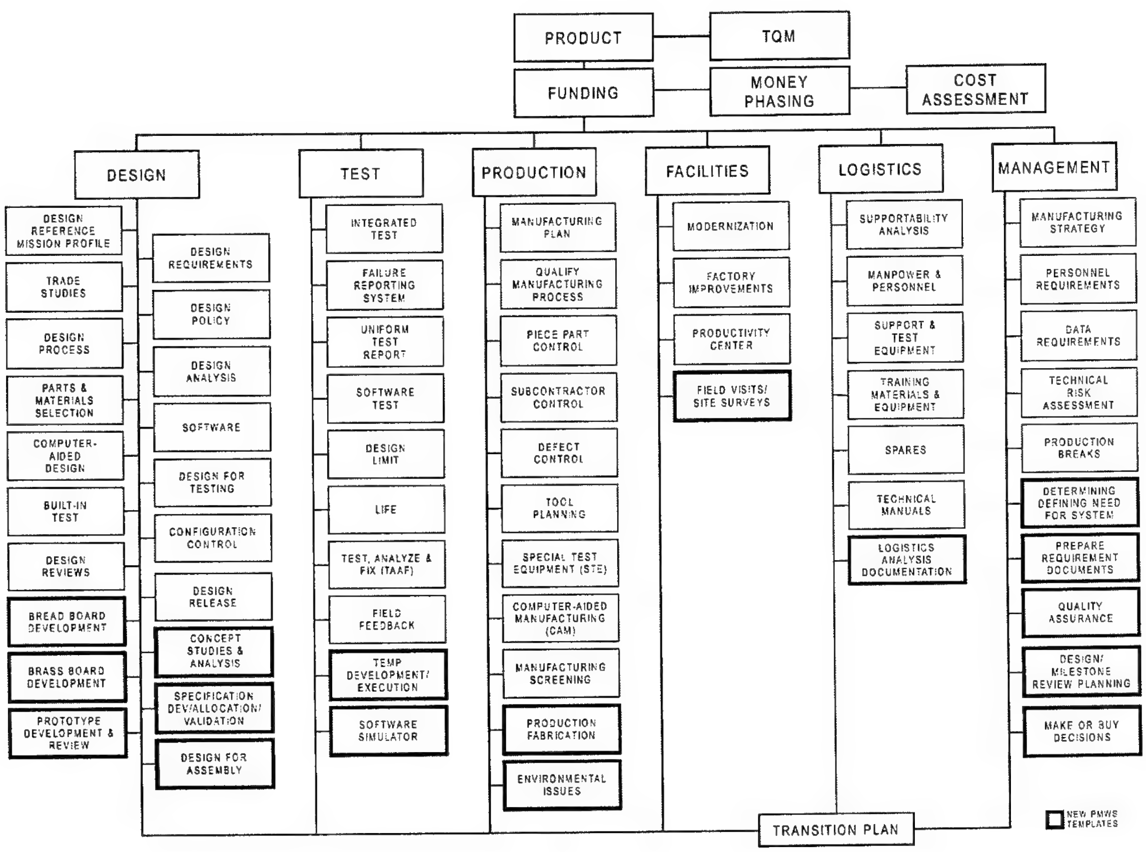
Appendix C

Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

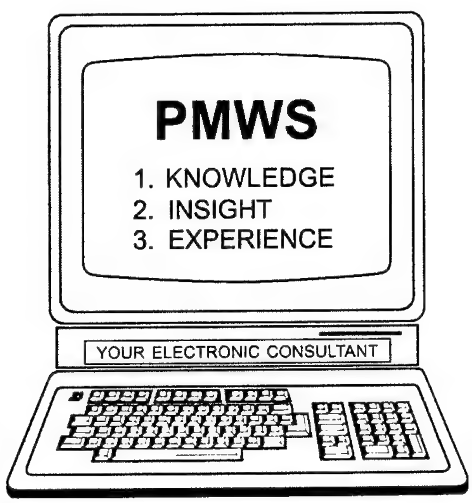
"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D
BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at http://www.bmpcoe.org), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.

PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.



KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition personnel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** con-tains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at http://www.bmpcoe.org. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.

Appendix E

Best Manufacturing Practices Satellite Centers

There are currently ten Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; and train regional personnel in the use of BMP resources such as the BMPnet.

The ten BMP satellite centers include:

California

Chris Matzke
BMP Satellite Center Manager
Naval Warfare Assessment Division
Code QA-21, P.O. Box 5000
Corona, CA 91718-5000
(909) 273-4992
FAX: (909) 273-4123
cmatzke@bmpcoe.org

Jack Tamargo
BMP Satellite Center Manager
257 Cottonwood Drive
Vallejo, CA 94591
(707) 642-4267
FAX: (707) 642-4267
jtamargo@bmpcoe.org

District of Columbia

Chris Weller
BMP Satellite Center Manager
U.S. Department of Commerce
14th Street & Constitution Avenue, NW
Room 3876 BXA
Washington, DC 20230
(202) 482-8236/3795
FAX: (202) 482-5650
cweller@bxa.doc.gov

Illinois

Thomas Clark
BMP Satellite Center Manager
Rock Valley College
3301 North Mulford Road
Rockford, IL 61114
(815) 654-5515
FAX: (815) 654-4459
adme3tc@rvc.cc.il.us

Iowa

Bruce Coney
Program Manager
Iowa Procurement Outreach Center
2273 Howe Hall, Suite 2617
Ames, IA 50011
(515) 294-4461
FAX: (515) 294-4483
bruce.coney@ciras.iastate.edu

Louisiana

Al Knecht
Director
Maritime Environmental Resources & Information Center
Gulf Coast Region Maritime Technology Center
University of New Orleans
810 Engineering Building
New Orleans, LA 70148
(504) 626-8918 / (504) 280-6271
FAX: (504) 727-4121
atk@neosoft.com

Michigan

Jack Pokrzywa
SAE/BMP Satellite Center Manager
755 W. Big Beaver Road, Suite 1600
Troy, MI 48084
(248) 273-2460
FAX: (248) 273-2494
jackp@sae.org

Roy T. Trent
SAE/BMP Automotive Manufacturing Initiative Manager
755 W. Big Beaver Road, Suite 1600
Troy, MI 48084
(248) 273-2455
FAX: (248) 273-2494
bounder@ees.eesc.com

Ohio

Karen Malone
BMP Satellite Center Manager
Edison Welding Institiute
1250 Arthur E. Adams Drive
Columbus, Ohio 43221-3585
(614) 688-5111
FAX: (614) 688-5001
karen_malone@ewi.org

Pennsylvania

Sherrie Snyder
BMP Satellite Center Manager
MANTEC, Inc.
P.O. Box 5046
York, PA 17405
(717) 843-5054, ext. 225
FAX: (717) 854-0087
snyderss@mantec.org

Tennessee

Tammy Graham
BMP Satellite Center Manager
Lockheed Martin Energy Systems
P.O. Box 2009, Bldg. 9737
M/S 8091
Oak Ridge, TN 37831-8091
(423) 576-5532
FAX: (423) 574-2000
tgraham@bmpcoe.org

Appendix F
Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, The Department of Commerce, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Anne Marie T. SuPrise, Ph.D.
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
annemari@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the Great Lakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Mr. James Ray
Center of Excellence for Composites Manufacturing Technology
c/o GLCC, Inc.
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3708
FAX: (803) 822-3710
jrglcc@glcc.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
One International Plaza
Suite 600
Philadelphia, PA 19113
(610) 362-1200
FAX: (610) 362-1290
criswell@aci-corp.org

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implemen-tation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
Johnstown, PA 15904-3374
(814) 269-2532
FAX: (814) 269-2501
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

Point of Contact:
Mr. David P. Edmonds
Navy Joining Center
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
(614) 688-5096
FAX: (614) 688-5001
dave_edmonds@ewi.org

Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The EMTC also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
Mr. John Brough
Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
101 Strauss Avenue
Building D326, Room 227
Indian Head, MD 20640-5035
(301) 744-4417
DSN: 354-4417
FAX: (301) 744-4187
mt@command.ih.navy.mil

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST), was formerly known as Manufacturing Science and Advanced Materials Processing Institute. Located at the Pennsylvania State University's Applied Research Labortory, the primary objective of iMAST is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechnical drive transmission techologies, materials science technologies, high energy processing technologies, and repair technology.

Point of Contact:
Mr. Henry Watson
Institute for Manufacturing and Sustainment Technologies
ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 865-6345
FAX: (814) 863-1183
hew2@psu.edu

National Network for Electro-Optics Manufacturing Technology

The National Netowork for Electro-Optics Manufacturing Technology (NNEOMT), a low overhead virtual organization, is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. NNEOMT is managed by the Ben Franklin Technology Center of Western Pennsylvania.

Point of Contact:
Dr. Raymond V. Wick
National Network for Electro-Optics Manufacturing Technology
One Parks Bend
Box 24, Suite 206
Vandergrift, PA 15690
(724) 845-1138
FAX: (724) 845-2448
wick@nneomt.org

Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and focuses primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas focuses on process improvements.

Point of Contact:
Dr. John Crisp, P.E.
Gulf Coast Region Maritime Technology Center
University of New Orleans
College of Engineering
Room EN-212
New Orleans, LA 70148
(504) 280-5586
FAX: (504) 280-3898
jncme@uno.edu

Manufacturing Technology Transfer Center

The focus of the Manufacturing Technology Transfer Center (MTTC) is to implement and integrate defense and commercial technologies and develop a technical assistance network to support the Dual Use Applications Program. MTTC is operated by Innovative Productivity, Inc., in partnership with industry, government, and academia.

Point of Contact:
Mr. Raymond Zavada
Manufacturing Technology Transfer Center
119 Rochester Drive
Louisville, KY 40214-2684
(502) 452-1131
FAX: (502) 451-9665
rzavada@mttc.org

Appendix G
Completed Surveys

As of this publication, 119 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Anne Marie T. SuPrise, Ph.D., Acting Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
annemari@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.)
	Texas Instruments Defense Systems & Electronics Group - Lewisville, TX
	General Dynamics Pomona Division - Pomona, CA
	Harris Corporation Government Support Systems Division - Syosset, NY
	IBM Corporation Federal Systems Division - Owego, NY
	Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA
	ITT Avionics Division - Clifton, NJ
	Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA
	UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ
	General Dynamics Fort Worth Division - Fort Worth, TX
	Texas Instruments Defense Systems & Electronics Group - Dallas, TX
	Hughes Aircraft Company Missile Systems Group - Tucson, AZ
	Bell Helicopter Textron, Inc. - Fort Worth, TX
	Litton Data Systems Division - Van Nuys, CA
	GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO
	Northrop Corporation Aircraft Division - Hawthorne, CA
	Litton Applied Technology Division - San Jose, CA
	Litton Amecom Division - College Park, MD
	Standard Industries - LaMirada, CA
	Engineered Circuit Research, Incorporated - Milpitas, CA
	Teledyne Industries Incorporated Electronics Division - Newbury Park, CA
	Lockheed Aeronautical Systems Company - Marietta, GA
	Lockheed Corporation Missile Systems Division - Sunnyvale, CA
	Westinghouse Electronic Systems Group - Baltimore, MD
	General Electric Naval & Drive Turbine Systems - Fitchburg, MA
	Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA
	TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA
	TRW Military Electronics and Avionics Division - San Diego, CA
	MechTronics of Arizona, Inc. - Phoenix, AZ
	Boeing Aerospace & Electronics - Corinth, TX
	Technology Matrix Consortium - Traverse City, MI
	Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ *Resurvey of Texas Instruments Defense Systems & Electronics Group* - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN *(Resurvey of Control Data Corporation Government Systems Division)* Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA *(Resurvey of Rockwell International Corporation Collins Defense Communications)* Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO *(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)* Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX *(Resurvey of General Dynamics Fort Worth Division)* Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH Lawrence Livermore National Laboratory - Livermore, CA Sharretts Plating Company, Inc. - Emigsville, PA Thermacore, Inc. - Lancaster, PA Rock Island Arsenal - Rock Island, IL Northrop Grumman Corporation - El Segundo, CA *(Resurvey of Northrop Corporation Aircraft Division)* Letterkenny Army Depot - Chambersburg, PA Elizabethtown College - Elizabethtown, PA Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA Strite Industries Limited - Cambridge, Ontario, Canada Northrop Grumman Corporation - El Segundo, CA Corpus Christi Army Depot - Corpus Christi, TX Anniston Army Depot - Anniston, AL Naval Air Warfare Center, Lakehurst - Lakehurst, NJ Sierra Army Depot - Herlong, CA ITT Industries Aerospace/Communications Division - Fort Wayne, IN Raytheon Missile Systems Company - Tucson, AZ Naval Aviation Depot North Island - San Diego, CA *U.S.S. Carl Vinson* (CVN-70) - Commander Naval Air Force, U.S. Pacific Fleet Tobyhanna Army Depot - Tobyhanna, PA
1999	Wilton Armetale - Mount Joy, PA Applied Research Laboratory, Pennsylvania State University - State College, PA Electric Boat Corporation, Quonset Point Facility - North Kingstown, RI NASA Marshall Space Flight Center - Huntsville, AL Orenda Turbines, Division of Magellan Aerospace Corporation - Mississauga, Ontario, Canada
2000	Northrup Grumman, Defensive Systems Division - Rolling Meadows, IL

INTERNET DOCUMENT INFORMATION FORM

A . Report Title: Best Manufacturing Practices: Report of Survey Conducted at Northrop Grumman Defensive Systems Division, Rolling Meadows, IL

B. DATE Report Downloaded From the Internet: 12/20/01

C. Report's Point of Contact: (Name, Organization, Address, Office Symbol, & Ph #): Best Manufacturing Practices
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F. The foregoing information was compiled and provided by:
DTIC-OCA, Initials: __VM__ **Preparation Date 12/20/01**

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